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SOCIETY OF ENGINEERS

ESTABLISHED MAY 1854

Journal and

TRANSACTIONS FOR 1909

AND

GENERAL INDEX 1857-1909

EDITED BY

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A.M.Inst.C.E., M.R.S.I.
SECRETARY.

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CONTENTS.

PAGE

INAUGURAL ADDRESS OF THE PRESIDENT, E. J. SILCOCK .. 1

A NEW TEST FOR CONCRETE. BY J. S. OWENS 29

THE CORROSION OF STEEL REINFORCEMENT IN CONCRETE. BY E. R. MATTHEWS 61

THE INFLUENCE OF RAINFALL ON THE DESIGN OF SEWERS. BY C. A. BATTISCOMBE 93

THE SINLUMKABA (BURMA) FERRO-CONCRETE BRIDGE. BY W. E. HALDWELL 121

VACATION VISITS 141

STATUS PRIZE ESSAY, 1909. BY G. A. THOMAS 147

SOME OBSERVATIONS ON THE CHEMISTRY AND BACTERIOLOGY OF SEWAGE PURIFICATION. BY D. SOMMERVILLE 175

VISIT TO LEEDS 203

STEAM WAGONS. BY J. C. CORNOCK 207

THE MECHANICS OF DUST. BY C. H. W. BIGGS 225

OBITUARY 244

ANNUAL REPORT OF COUNCIL AND STATEMENT OF ACCOUNTS, 1909 247

PREMIUMS AWARDED FOR 1909 256

INDEX 259

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

COUNCIL AND OFFICERS FOR 1909.

Council.

President—EDWARD JOHN SILCOCK.

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FRANCIS GEORGE BLOYD.

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AUGUSTUS WILLIAM DE ROHAN GALBRAITH.
TOM EDWARD BOWER.
ROBERT WELLESLEY ANTHONY BREWER.
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,, (1907) RICHARD ST. GEORGE MOORE.
,, (1906) MAURICE WILSON.
,, (1905) NICHOLAS JAMES WEST.
,, (1904) DAVID BUTLER BUTLER.
,, (1903) JAMES PATTEN BARBER.

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Trustees — SIR DOUGLAS FOX.
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Bankers—LLOYDS BANK (LIMITED).
Secretary—A. S. E. ACKERMANN, B.Sc. (ENGG.).

OFFICES:
17, VICTORIA STREET, WESTMINSTER, S.W.
Hours, 10 *a.m. to* 4 *p.m.; Saturdays,* 10 *a.m. to* 1 *p.m.*
TELEPHONE: 244, VICTORIA.
TEL. ADDRESS: "WINDOLITE, LONDON."

PLACE OF MEETING.
THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL.

1ST JANUARY, 1909.

PAPERS AND PREMIUMS.

THE Council of the Society of Engineers invite original communications from Members and Associates, as well as from gentlemen who do not belong to the Society, on subjects connected with any branch of Engineering.

For any papers that may be considered sufficiently meritorious the Council may at discretion award one or other of the following Premiums, viz. :—

1. THE PRESIDENT'S PREMIUM, given annually by the President, and consisting of a Gold Medal of the value of Five Guineas.
2. THE BESSEMER PREMIUM, provided for annually by the late Sir Henry Bessemer, F.R.S., Honorary Member, of the value of Five Guineas.
3. THE SOCIETY'S PREMIUMS, given annually by the Society, of an aggregate value not exceeding Twenty Pounds.

To the above will be added in 1909 the NURSEY PREMIUM, founded as a memorial to the late Mr. Perry F. Nursey, and the BERNAYS PREMIUM provided by the late Mr. Joseph Bernays.

The number and value of the Society's Premiums are decided by the Council according to the number of meritorious papers read during the year.

By the Rules of the Society, Members of Council are disqualified from receiving Premiums for Papers.

SOCIETY OF ENGINEERS' TRANSACTIONS FOR 1909.

February 1st, 1909.

INDUCTION OF THE PRESIDENT,

EDWARD JOHN SILCOCK.

THE Chair was occupied at the commencement of the meeting by Mr. JOSEPH WILLIAM WILSON, the retiring President.

The Minutes of the last ordinary meeting were read, confirmed, and signed.

The Chairman: With great regret I have to announce the death of Dr. Francis Elgar, LL.D., F.R.S. He was our oldest honorary member, having been elected in 1886, and we have always appreciated the honour he thus conferred upon us. We all know what a distinguished position he held in our Profession, and I now desire, on behalf of the Council and Members of our Society, to express our deep regret at his decease, and our sympathy with the members of his family.

The names of candidates proposed for election were then read by the Secretary.

The Chairman: I have now the pleasing duty of presenting the premiums which have been awarded by the Council for the papers read before the Society during the past year. The first in importance is the President's Gold Medal, which has been awarded to Professor Robert H. Smith for his paper upon "The Design and the Waste and Wear of Wheel Teeth." We greatly appreciate the fact that Professor Smith has read us this paper and offered it to us for our Transactions. It was a communication of great erudition and value from all points of view, and one which led to an interesting discussion. I have much pleasure in handing this medal to Professor Smith.

Professor R. H. Smith, in acknowledging the award of the President's Gold Medal, said: Mr. Chairman and gentlemen, I would prefer to tender in respectful silence my thanks for this beautiful medal and my appreciation of the honour done me in awarding it for my paper on toothed gearing, but I am told that it is the custom in this Society to express one's gratitude in words. It is difficult to choose a short phrase sufficient for the purpose. I can only say how much I admire the great hospitality of the

Society of Engineers in accepting papers from outsiders, and how I wonder still more at their extreme generosity in bestowing their medals on those who are not members of the Society.

The number of existing engineering societies is great—too great for any individual to aspire to membership in nearly all that he might like to belong to, and whose proceedings interest him. Some years ago I resigned membership of more than half of those I belonged to because I could not attend more than one-fifth of their meetings, because I could no longer find room on my bookshelves for their voluminous Proceedings, and because I had not the heart to burn the accumulation of these Proceedings piled on the floors.

The supply of papers to all these Societies seems to be inexhaustible and is proof of the unflagging energy with which engineering mankind pursues the study of mechanical science. This explains why so many societies exist. Their *raison d'être* is to encourage and stimulate engineers to develop and publish improvements in engineering practice without hope of pecuniary advantage to themselves and to the general profit of the profession at large. Thus, the only inducement that can be offered by the societies is kudos ; and it is offered effectively. The kudos of the Society of Engineers' Medal is very great. It encourages me to prolong an already long career of sacrifice on the altar of engineering science ; and I trust that this and other societies will, by dint of patient and slumberless listening and by bestowing gold medals, go on rearing and training this great army of fanatic writers of papers to never-ending sacrificial rites and self-immolation on this same altar of the greedy god of human progress.

The other Premiums were then distributed.

Mr. A. W. de R. Galbraith, in accepting the Bessemer Premium of books on behalf of **Mr. Herbert Chatley,** said : I have very much pleasure in accepting this valuable present of books on behalf of my friend Mr. Chatley. He has been recently appointed professor of civil engineering at the Tong Shan Engineering College under the Imperial Railways of North China. He is only twenty-three years of age and I think that he has made a rather remarkable record for a young man. He is a National Silver Medallist in building construction (Dept. of Education). In 1906, when he was just twenty-one, he obtained the B.Sc. (Engineering) of London University. He is the author of two or three technical and professional works, one of which, on Mechanical Flight, is going through its second edition. He is an authority on the theoretical investigation of aviation and has this year won the Society's Bessemer prize for a paper on that subject. I think that you will agree with me that this is a most remarkable record for such a young man.

Mr. Arthur H. Allen, in accepting the Society's Premium of books, said : When I undertook to read the paper on the Metric System here before you I was very pleased to do so, in the knowledge that I might do a little towards advancing the cause of the metric system in this country. I thought myself quite sufficiently rewarded, and I never anticipated such a present as you have made me to-night. I am sure that I cannot express my thanks too sincerely for this generous award.

Mr. Henry Conradi also thanked the Society for the Premium of books awarded to him.

The Chairman announced that as Mr. H. C. Duncan Scott was in Egypt, the Society's Premium of books awarded to him would be forwarded by the Secretary.

Continuing, he said : I have to express the thanks of the Society to the other gentlemen who have read us papers ; first, Mr. R. W. A. Brewer for his paper on " The Flow of Liquid Fuel through Carburettor Nozzles." Mr. Brewer was good enough in 1907 to read us a paper which received a premium, and we much appreciate his writing another, a continuation of the former one. You will see that the Council have recognised what Mr. Brewer has done by nominating him on the Council of the Society, and the members by electing him. Also we are much indebted to Mr. A. J. Metcalfe for reading us a paper on the " Treatment and Formation of Road Surfaces," which is a valuable addition to our Transactions.

Now, gentlemen, my last and most pleasing duty is to introduce to you your new President, Mr. Edward John Silcock. Mr. Silcock has been a member of the Council for the last six years, and has regularly attended our Council and ordinary meetings. The Council know and appreciate him thoroughly, and we are quite certain that he will make a very excellent President. Under his regime the Society is going on to still greater things. It is a matter to congratulate him upon that, during his year of Presidency, our amalgamation with the Civil and Mechanical Engineers' Society will probably take place. (Addressing Mr. Silcock, the Chairman continued) : I beg to offer you this certificate of your election as President for 1909 and I hope that you will have a very successful year of office.

The Chairman then invested the incoming President, Mr. E. J. Silcock, with the badge of office as President, and vacated the Chair.

Mr. E. J. Silcock succeeded to the Chair and said : Gentlemen, the first privilege that I shall claim is to propose a vote of thanks to Mr. J. W. Wilson, our retiring President. I feel that this is not one of the ordinary votes of thanks which are passed to a retiring officer, because Mr. Wilson has rendered very special services, and has therefore special claims upon our thanks. As you know, he occupied the position of President on a previous occasion some years ago, and the term of office which he is now concluding is in reality two years of occupation of the Chair, because, in the absence of Mr. St. George Moore from this country, Mr. Wilson had to act as President and to preside over our meetings during the greater part of Mr. Moore's year of office. In addition to his having served for two years as President, there have been very special circumstances connected with that term which have made it one of very great importance, and the duties have been exceedingly onerous. Owing to the death of our lamented friend, Mr. Nursey, who occupied the position of Secretary for so long, it became necessary to appoint a new secretary, and, as you know, that office is one of the highest importance to the Society. We consider ourselves fortunate in having secured such an excellent secretary as Mr. Ackermann, but even he, without Mr. Wilson's guiding hand, would, I am sure, have often felt himself at a loss. It has frequently happened that Mr. Wilson's wide experience and long acquaintance with the affairs of the Society have enabled him to assist the Secretary in carrying out his duties. I am quite sure that when we passed from the reign of one secretary to that of another in such an easy manner it was largely due to the assistance and tact and goodwill of our Past-President, Mr. Wilson. In these circumstances I feel sure that you will agree with me that we owe him especial thanks for the way in which he conducted the business of the Chair. I have very great pleasure in moving that the best thanks of the Society be given to him therefor.

Mr. Diogo A. Symons : Mr. Chairman and gentlemen, I have very much pleasure in seconding this resolution. After the able way in which Mr. Silcock has proposed this vote of thanks it is needless for me to say many words. We all know what an enormous amount of work has been done by the President during the past Session. The year for many reasons has been a most arduous and difficult one, and I consider that a hearty vote of thanks is due to Mr. Wilson for the admirable way he conducted the affairs of the Society during his term of office.

The President : Gentlemen, you have heard the resolution and I am sure that it only needs your acclamation to carry it. (Applause.)

Mr. J. W. Wilson : Mr. Silcock, Mr. Symons, and gentlemen, I am very much indebted to you for this vote of thanks. I am sure you will understand that my work for the Society has been a labour of love. One is not connected with a Society like this for thirty-six years without becoming very much attached to it. After my First Presidency in 1892, I thought that there was a possibility of working round to the same position again, by passing once more through the different preliminary stages, with more experience than before, and I am glad to have been the first President to do so. Although this is the same old Society, we have made many changes and improvements since former days. For instance, we used to hold our ordinary meetings at the Society's offices, in very inadequate rooms, which had to suffice for us at the time. Yet we often had very good papers which you would be interested to read in the volumes of our old Transactions, of which we have plenty of reserve copies. There were good papers by very good men ; and some very good men were our Presidents. I should like to say how much I appreciate the value of the papers that we have had during the past year, as well as the excellence of the discussions on them. I am only sorry that during my year of office there has not been one of my colleagues here, who were with me on the Council in 1892.

I desire to thank sincerely all the members of the Council and especially our good Honorary Treasurer and Secretary, Mr. Butler, for the way in which they have supported me. We have had a good hard year's work, involving forty or fifty different Council, Committee and other meetings, trips, etc., and we have done our best to further the interests of the Society.

I must also thank Mr. Ackermann, our indefatigable Secretary, who seems to revel in hard work. He undertakes all sorts of things which give him extra trouble, in the interests of the Society, and he has a large share in its welfare and progress.

I am confident that there is a great era of success before this Society. We are taking up new developments, to some of which I believe our President is going to allude to-night. In these I know we shall have the support of all members of the Society ; and I hope that when the before-mentioned amalgamation has taken place, we shall have yet better attendances at our meetings.

In conclusion, I thank you very much for the kind appreciation which you have shown of whatever I may have been able to do for the Society of Engineers during the past year.

The President then delivered the following Inaugural Address :

GENTLEMEN,—My first duty is to thank you very cordially for the honour you have done me in placing me in the proud position of President of the Society of Engineers, and thus allowing me to take a place in the long line of distinguished Engineers who have been my predecessors in this Chair. I venture to hope that you will accord me your active and indulgent support during the coming year, as without this I should not feel myself competent to undertake the duties of the office.

The Society of Engineers, as you know, was founded 55 years ago and includes amongst its members Engineers engaged in every branch of a many-sided profession : the total Membership on December 31st, 1908, numbered 551, which constitutes a record.

The numbers in the three classes for the last three years are as follows :—

	1906.	1907.	1908.
Honorary Members ..	19	20	20
Members	376	376	360
Associates	151	152	171
Totals	546	548	551

From this you will see that there has been a small increase year by year of total membership, but that the class of Members has slightly decreased.

The following comparative table of losses and gains may be of interest :—

	1904.	1905.	1906.	1907.	1908.
Losses from deaths, resignations, and other causes	30	46	37	37	46
Gains by elections of new Members and Associates	40	39	40	39	49

It will be noted that the losses in 1908 were unusually heavy, so that the increased total membership for that year is all the more satisfactory. There is also another feature which affects the roll for 1908, viz. :—the removal from our list of the names of several members whose subscriptions were in arrears. Your Council have taken this action as they felt that these members were a source of weakness rather than strength to the Society, and that we would be better in every way without such lukewarm supporters than with them.

Whilst speaking on this subject I should like to refer to the apparent lack of interest taken by the Members generally in the proceedings of the Society, and to urge upon you the importance of giving it your heartiest support by preparing papers, by regular attendance at the meetings, and by taking part in the discussions.

In a Society such as ours, which embraces all classes of Engineers, the papers brought forward cover a wide field, and no doubt it frequently happens that the subject of a paper does not appeal to some of our Members and they prefer some more social form of entertainment to attendance at our meeting ; but, gentlemen, there is always something to be learned out of every paper and discussion : the various branches of our work are so interdependent that they cannot be treated in a detached manner, and even if you do not feel yourself competent to add to the value of a debate by bringing forward your own personal experience in the particular subject under discussion, you may attend the meetings with the certain conviction that your evening will not be wasted.

We are often favoured by the presence of Visitors who are specially interested in and qualified to speak on the subject matter of the Paper : indeed, I regard this as one of the most useful functions of our Society, which is so catholic in its interests that it can attract to its meetings not only Engineers but distinguished members of other professions to take part in our deliberations.

But, gentlemen, is it creditable to us to have the debates entirely conducted by our Visitors ? However pleased we may be to see them here we should not, I think, permit ourselves to be overshadowed by them. When one considers the paucity of Members present at some of our meetings and the large proportion of Visitors one cannot help feeling that the Society is paying a very poor compliment to the Authors of the Papers and that it cannot be expected that the best men will go to the trouble of preparing communications to be delivered to empty benches. I have spoken very plainly on this subject for it is one on which I feel strongly, and I venture to make a personal appeal to the Members to put more enthusiasm into their membership and to regard regular attendance and participation in the debates as of the highest importance. If I could by any means galvanize this Society into more active life I should do so with the greatest pleasure, but it rests with you gentlemen, and I trust that my words may have some effect.

The work of the Council during the past year has been of a progressive character and new departures have been made in the scope of their operations. Amongst these I may mention the revised form of issuing Transactions : the granting of legal advice to Members ; the Employment Register ; and the Business Directory.

The Members have now the option of having the Transactions of the Society sent to them in the old form of one complete volume per annum, or they can receive them in smaller instalments, each of which contains the report of a separate meeting with a complete Paper and the discussion thereon, the section being issued as soon as possible after the respective Papers have been read. About two-fifths of our members have adopted this method of taking their Proceedings and only one of these has reverted to the yearly volume form.

The Council hope that by adopting this course Members who are unable to attend the Meetings regularly will be able to keep in closer touch with the Proceedings of the Society, and will then take a greater interest in and receive greater benefit from the Papers contributed.

The granting of legal advice on Professional matters is another development which, with the generous assistance of our Honorary Solicitors, has been undertaken by the Society. At present this has only been put forward as a tentative measure as the Council feel that they do not wish to pledge the Society to too big an expenditure until they have had an opportunity of gauging the use which Members are likely to make of the privilege.

Up to the present time, however, no applications have been made for assistance in this direction. Whether this arises from the fact that Members do not realise what it is that is offered to them, I cannot say. On the other hand it may be that no demand exists for help of this kind, and that the Members generally do not find themselves in positions which require the services of a legal adviser. If this be the true explanation of the absence of any applications, I congratulate the Members upon their happy condition.

The Employment Register has been instituted with a view to bringing employers into touch with Members of the Society who are capable of occupying any positions which may be vacant. This Register, again, has not been largely resorted to by Members seeking employment, and unfortunately the same may be said of possible employers, but the Council intend to take steps to bring the Register more prominently before large firms who are likely to become employers of Engineers, and they confidently appeal to the representatives of all such firms who may be Members of the Society to utilise this branch of the Council's work when needing Assistant Engineers.

The Business Directory is kept in the form of a Card Index and although only recently introduced has been used to the benefit of Members on several occasions. In this matter again Members do not appear to fully appreciate the possible benefits which may be conferred upon them if they will take the trouble to fill up the necessary cards and forward them to the Secretary. I strongly advise all Members to do this in order that the Secretary may have at his command the fullest information to assist him in directing business into channels in which it is likely to benefit the Members.

In addition to these matters the Council, as you are aware, have had under consideration the question of amalgamation with the Civil and Mechanical Engineers' Society. As the result of negotiations which have taken place, between the members of the Joint Committee of the two Societies, the general outline of a scheme has been arrived at and there seems every prospect of this proposal being carried to a successful issue. I have great hopes that the amalgamation may be effected during my year of office as your President.

The Civil and Mechanical Engineers' Society will celebrate the Jubilee of its formation during the present year and there is a natural desire on the part of the Members of the Society to postpone the amalgamation until after that event. When, however, the 50 years of their life is completed, they are prepared, I believe, to throw in their lot with us, and I think that this will result in a great strengthening of the usefulness of the combined Societies.

To my mind the influence of one strong Society is greater than that of two less powerful bodies. There can be no question that by uniting our own Society with that of the Civil and Mechanical Engineers we shall form a very strong representative body of Engineers whose usefulness will extend over a wide area. The stage which proceedings have now reached involves the drafting of new Articles of Association and Rules to regulate the new Society. This will give the Joint Councils the opportunity of reviewing the existing Rules of both Societies and selecting from them the best points in each, and will also enable modifications to be made to meet the views of Members wherever possible. Under these circumstances, we earnestly invite the co-operation of all Members and shall be glad to receive any suggestions as to new Rules or modifications in existing Rules which may be thought desirable in the general interests of the Society.

Your Council are also considering what steps can be taken to assist and push forward the general movement which is now prominent in the minds of many Engineers, both in this country and on the Continent, and also in America, with regard to the subjects of registration, rules for the guidance of Members in their professional conduct, and scales of minimum pecuniary remuneration.

The opinion is largely gaining ground that Engineering has become such a highly technical profession that the men who have received a proper education and scientific training combined with practical experience, and are thus fully equipped for carrying out the duties imposed upon them by their profession, should be registered and protected from competition from uneducated and ignorant competitors, in the same way as are members of other professions such as Medicine and the Law.

At the present time there is nothing to prevent any individual from placing the letters "C.E." after his name, and much confusion exists in the minds of the public through the great variety of letters which are commonly appended to the names of men practising in the various branches of engineering. It seems high time that there should be some recognised qualification by which the public can know that a person possessing it is, within reasonable limits, properly equipped to advise upon engineering matters. Rules for the guidance of engineers in matters of professional etiquette are at the present time exceedingly nebulous, and there is no recognised Court of Appeal which will take cognizance of breaches of the unwritten laws of conduct or will take the initiative in formulating definite rules.

The question of the rates for remuneration, particularly for Consulting Engineers, is again a subject on which much difference of opinion exists, and in which unfortunately, through competition and the absence of a Court of Appeal in matters of etiquette, much dissatisfaction exists. It surely must be recognised that it would be in the interests of the profession if some scales of charges were formulated and put forward by a body representing the whole Engineering profession.

It is hoped that the Institution of Civil Engineers will undertake the important duty of dealing with these questions, and your Council are quite willing to co-operate with them in so doing. Should the senior Engineering Institution in the World fail to realise the importance of its position and to deal with these most vital questions, it will be for your Council to consider whether they should not themselves assume that responsibility.

From what I have said you will, I think, gather that your Council, apart from the work which has come before your immediate notice in connection with the ordinary meetings and visits, have during the past year been busily occupied in your interests, and there is every indication that the coming year will be at least as important in these respects as the last.

Having dealt with these domestic questions, I propose now to follow the time-honoured custom of addressing to you some few remarks upon the branch of our profession with which I am most familiar.

In 1903, your President, Mr. J. P. Barber, in his presidential address, drew attention to the fact that he was the first Municipal Engineer to occupy that position. Although I am not myself now a Corporation Official I have spent many years of my life in Corporation service, and since joining the ranks of Consulting Engineers my work has been largely concerned with municipal undertakings. Under these circumstances I propose to speak to you upon some subjects which are of high importance to municipal authorities.

As has been pointed out on many occasions, the work of a municipal engineer is of a very varied character. It may be thought that in a country so highly civilised as Great Britain there would be little or no municipal work to be done, and that the position of a Corporation Engineer would be a sinecure.

Although it is true that the Local Authorities of this country have expended vast sums of money on public works and that in most towns there are already in existence Waterworks, Sewerage Works, Gas Works, Electric Light, Tramways, and undertakings of a like character, yet the continual growth of population, the advances made by Sanitary Science and the imposition of new burdens by the Legislature combine to keep Municipal Corporations constantly moving, and I regard the profession of a Municipal Engineer as being one in which there is every prospect of continued prosperity.

The importance of the works undertaken by the Municipalities of this country can to some extent be gauged by the loans contracted by them. The Local Government Board have, since the beginning of the present century, sanctioned borrowing to the extent of an average of 13½ million pounds annually. This is exclusive of loans authorised through the agency of Acts of Parliament, which must aggregate to a further large sum. These huge loans are expended entirely upon capital account, chiefly in works of an engineering character, and take no account of the money expended out of current rates for maintenance of roads, sewerage works and other non-productive municipal undertakings. To the younger members of the Society, who have yet their future to look forward to, I commend the Municipal service as a fine training ground for budding Engineers. I know of no better school in which a man can learn not only Engineering but how to deal with all classes of men, than can be found in the employment of a Municipal Corporation.

One of the chief functions of a Municipality is the supply of a pure and wholesome water for the use of its inhabitants. In many cases the Local Authorities have failed to realise the importance of this responsibility and have left the question to be settled by the enterprise of private individuals through the means of a Water Company.

Taking the Water Companies throughout the country generally, I believe they use their best endeavours to supply an adequate and wholesome water to their customers, but as a broad principle it is now generally recognised that the water supply should be in the hands of the Local Authority and that no questions of private gain should be permitted to interfere with the supply of a commodity on which depends the health of the public.

Parliament has so far accepted this principle that it invariably favours a Local Authority where there are competing Bills before it, and Parliamentary Committees are usually prepared to sanction Bills authorising the purchase by the Local Authority of the undertaking of an existing Water Company, unless the latter holds an exceptionally strong position.

This is a section of the public service which has involved large expenditure of public money and the construction of extensive works and has provided employment for many members of the Engineering profession. There are at the present time a number of exceptionally large works in progress for improving the supply of the larger towns in the North of England, and the question of bringing Welsh water to London is still in the air, although it has been to a certain extent deferred by the purchase of the London Water Companies and the amalgamation of the London Water Supply under a Water Board.

As a result of the keen competition for gathering grounds for surface water supplies in the North of England and Wales, the available catchment areas are now almost entirely occupied and year by year the difficulty increases of finding suitable sites for the construction of waterworks for large towns.

As the gathering grounds cannot be extended, some means will in future have to be devised for utilising more fully than heretofore the available rainfall. The directions in which this is most likely to be successful are by storing the storm waters now allowed to run to waste in wet seasons, by adopting pumping as an auxiliary to gravitation schemes, and by abstracting larger quantities of water from underground sources of supply.

In the South of England, where such a large proportion of the country overlies chalk or other absorbent strata from which water can be obtained by wells and pumping, the underground water may be said to be utilised to its fullest extent, but in the North of England, where surface water supplies are more in vogue, the underground water has been to a large extent neglected. This has been due to two causes, first the difficulty in intercepting water without going to great depths and incurring high cost in the construction of Wells, Galleries and Boreholes, and secondly from the fact that the underground waters have absorbed salts which have made them much harder than the surface water supplies which can be obtained from the carboniferous and older rocks. As the water is largely used for manufacturing purposes the quality of softness is one of extreme importance, and it will be necessary, therefore, not only to incur the high cost of works to intercept the underground water and pump it to a sufficient elevation, but also to adopt measures to reduce the degree of hardness and so produce a water suitable for the manufacturer.

The utilisation of flood waters has been limited to a great extent by cost of Reservoir construction. The proportion of Reservoir accommodation to be provided in any gathering ground has been largely based upon an empirical formula designed by the late Mr. Thomas Hawksley, who was, as you know, in his day regarded as the leading authority upon waterworks questions. His formula was intended to give the Reservoir capacity necessary to store and utilise the water falling upon a gathering ground over a period of the three consecutive driest years. The capital cost of Reservoirs is so great that water authorities have hesitated to extend their capacity beyond the limits necessary to deal with the three-year period.

It usually happens, however, that three dry years follow an excessively heavy rainfall. It is probable that in the future our views with regard to Reservoir accommodation will have to be revised and it will be necessary to provide storage for some of the excessive rainfall of the wet years and distribute it during the three dry years, or in other words our works must be designed to deal with the rainfall of four years instead of three.

Again, a great deal of water is now allowed to run to waste rather than incur the cost of lifting it to a suitable elevation.

In the North of England and Scotland, where the water supply is largely obtained by the collection of surface water in impounding reservoirs, the capital expenditure on reservoirs is so great that the Water Authorities shrink from incurring the additional cost of pumping. In the result one often finds schemes of water supply in which the reservoirs are situated at great distances from the consumers, whilst nearer at hand there are other gathering grounds, the waters of which are running to waste because they are too low to supply the town.

There is a great charm in a gravitation scheme as the absence of machinery makes the supply so certain and so automatic, but in the present days of high-class pumping machinery, breakdowns can be provided against by the provision of spare units, and after all it is only a matter of finance whether the annual cost of pumping will exceed the interest on the additional capital necessary to construct works at a greater distance from the population to be supplied.

When, however, the higher supplies are exhausted, as they already are to a large extent, we shall be compelled to utilise the lower catchment areas even if it becomes necessary to add the extra cost of lifting the water to that for the construction of impounding reservoirs for its storage.

A further method of utilising to the fullest extent our present supplies will be by the creation of Water Boards, with a Central Water Authority as a final Court of Appeal, who will be charged with the duty of dealing with the available waters in large areas, their sphere of authority being probably limited, not by our present county, town, or parochial limits, but by the area of the Watershed of a River or group of Rivers.

The necessity for such Controlling Bodies has now been recognised for some time amongst Waterworks Engineers and others who are engaged in the water supply industry, and the principle has been discussed many times before Parliamentary Committees. A notable instance of this was the case of the Derwent Valley Water Board, which was created at the suggestion of the Committee in the Houses of Parliament which had before it in one Session three Bills promoted by separate Corporations, each seeking to appropriate and utilise a proportion of the drainage area of the River Derwent.

After hearing the evidence put forward by the supporters of these Bills the Committee came to the conclusion that all three towns were entitled to a share of the water and that there were other Communities besides the Promoters whose interests should also be safeguarded. The Committee therefore threw out all three Bills and ordered the introduction of an entirely new Bill constituting the present Derwent Valley Water Board and apportioning the whole of the water available in the Valley amongst the various communities in the proportions which they considered just.

This is an example of the salutary effect of a controlling authority for the available water in any particular watershed, and is likely to have a permanent effect upon future legislation.

With regard to the general practice of Engineers in the construction of works of water supply there has been no recent new development of any importance except in relation to filtration. This process is now sometimes sub-divided by passing the water through a roughing filter to remove the grosser suspended solids before treating it on the ordinary sand filters. By this means the latter do not become so quickly clogged and can therefore be kept at work for longer periods without cleansing.

Recently in several cases Mechanical High-speed Filters have been adopted as a substitute for the older and more costly Sand Filters. The principle involved in this invention is the addition to the water of some chemical substance which coagulates the organic matter present and thus rapidly forms upon the surface of the filtering medium a gelatinous film through which the water may be passed at a high speed and yet undergo a high degree of purification.

Under the head of Sewerage immense sums of money have in the past been expended, and as the population increases the Sewerage Systems must be extended to keep pace with it.

The practice with regard to the construction of sewers has not undergone any marked change within recent years except by the introduction of reinforced concrete. This material, however, has not been very largely employed in this country owing principally to the reluctance of the Local Government Board to sanction long terms of years for the repayment of loans for work executed with it.

The attitude of the Board is no doubt justified by our lack of knowledge of the effect, upon steel bars buried in concrete, of a liquid like sewage, which contains such a variety of substances that one can never be certain what action it may have upon the materials with which it may come in contact.

On the other hand good brickwork, concrete, and glazed stoneware have undergone the test of time, and the Board is well assured when sanctioning loans for periods of 20 to 30 years for works of these materials that at the end of the term for which the loan is sanctioned the works will still be in a substantial state of repair, and will be useful for future service.

The tendency of modern practice has been in favour of using ordinary concrete for sewer construction to a much greater extent than formerly and this has been brought about by improvements in the manufacture and quality of cement, and has resulted in a considerable saving in capital expenditure upon large sewers.

In the smaller sizes of sewers the glazed stoneware pipe still holds its own, but there are numerous patents covering a great variety of methods of jointing the pipes, for the purpose of keeping them in true line and of excluding all subsoil water.

In designing sewers one of the first considerations to be determined is the quantity of stormwater which shall be admitted. Theoretically it is possible to separate stormwater from sewage proper, but in practice it is found that the cost of constructing two separate systems of drains as well as sewers is almost prohibitive and there are few examples of towns with complete systems of separate sewers for stormwater and sewage.

Even where stormwater is most rigidly excluded from the sewers there is a considerable fluctuation in the rate of flow during rainy weather, thus demonstrating that it is impossible to keep out all rain water. If fluctuations be once admitted it is generally better to face the problem of taking in a reasonable proportion of stormwater and making the sewers large enough to deal with it. Unfortunately the data at our command relating to the quantity of rain water to be dealt with are very inadequate. Much more information is required with regard to the rate of rainfall, as distinguished from the total fall, and also of the quantity of water which drains from a given area with a given rainfall.

The circumstances governing the latter figure vary to such an extent that it is exceedingly important that as many observations as possible should be taken and recorded for the use of Engineers in the future.

The proportion of impervious surface, the steepness of the ground, the character of the population inhabiting the area, and the degree to which surface water is included in the sewers all have their effect upon the quantity which has to be dealt with. It is only by observing and recording the flow in existing sewers, together with the records of rain gauges capable of measuring the rate at which the rain is falling, that one is enabled to make a proper estimate of the proportion of rainfall flowing off a given area. Even when the best possible data have been obtained it requires great care and the exercise of mature judgment to select from the records the particular basis applicable to any new area under consideration.

The next difficulty with which the Engineer has to grapple in designing a system of sewers is the probable growth of the population. It is usually found that amongst the smaller communities some new trade or manufacture has been commenced and has resulted in a very large increase in the population within a comparatively short time.

Estimates of future augmentation in population based upon such abnormal rates will almost certainly be in excess of the actual increase over a number of years. Even with larger towns a boom in a particular trade may cause a large increase to take place, which will not be maintained over a long period.

It therefore becomes necessary for the Engineer to very carefully consider the records of the past when dealing with future population and to discount to a certain extent the rapid increases over short periods due to abnormal conditions. For this purpose a curve representing graphically the increases from year to year, or decade to decade, will be found exceedingly useful as an assistance in arriving at a true conception of the normal rate of increase in the population.

In many instances Sewerage Works have been designed without true appreciation of these two main factors upon the sizes of sewers. In some cases sewers have been constructed much too large for present-day requirements, and time has shown that the increase in population has not been as rapid as was anticipated, and, by the exclusion of a large proportion of rain water, the sewers have not been fully occupied.

On the other hand it has far more frequently happened that the designer of the sewers has not been sufficiently bold in his conceptions, and he has put down sewers which have proved utterly inadequate for the duty imposed upon them. The result has been that they have become surcharged during heavy rainfalls to such an extent that flooding has taken place and serious claims for damages have been sent in to the Sanitary Authority.

Improvements in the methods of lifting sewage have placed in the hands of Engineers a new weapon to attack the problem of the concentration of the sewage at one point. Formerly when it was necessary to have a complete pumping station at every point at which it was desirable to lift sewage, the Engineer frequently found himself compelled to adopt one of two alternatives, either to construct sewers at gradients which were so flat that they were not self-cleansing or in the alternative to lay the sewers at such great depths that the cost of construction was enormously increased.

Now, however, the system of lifting sewage by means of Pneumatic Ejectors located in suitable positions in the district to be drained wherever required, compressed air being supplied from a central station, has been so perfected that it has enabled the Engineer to avoid these difficulties.

This system of pumping has been largely used both in this country and abroad, and in several cases recently electrically driven pumps, started and stopped automatically by floats, have been installed and are doing good work. As there are now electric cables laid in the streets of many towns for the purpose of supplying light and power, the cost of power distribution is already provided for, and the electrical method of sewage lifting should in the future be largely utilised.

Turning now to the question of Sewage Disposal, there has within the last few years been a very rapid advance in our knowledge. Going back ten years one finds that, except in experimental works, what we now know as bacteriological systems were not in existence.

Up to that time sewage purification had been effected practically by two classes of works, the first being land pure and simple, commonly known as Sewage Farming, and the second being some process for precipitating the matters in suspension ; the latter processes were largely covered by patents and therefore were proprietary.

It had long been recognised that the removal of suspended matters in sewage was not a complete cure, and that the organic matters in solution were subject to putrefactive changes which caused pollution of the streams into which the clarified effluents had been allowed to flow.

The treatment of sewage upon land had been successful in many instances, but in a very large proportion of cases the effluents from sewage farms had not been satisfactory.

This state of things was entirely brought about by using land either of unsuitable quality or insufficient quantity ; but even the worst land had some effect upon the organic matter in solution in sewage, and the Local Government Board when considering applications for loans to carry out works for Sewage Purification had made it a rule that whatever process of precipitation was first applied to sewage the effluent from that process should be treated upon land as a final stage in the purification.

In 1898 the Government appointed a Royal Commission to inquire into and report upon the whole question. This Commission is still sitting and quite recently issued its Fifth Report It was hoped that they would be able to arrive at some conclusions which would put the Sewage Purification problem upon a sound scientific basis, and that they would be able to select the best known process, and that this should be applicable to all cases.

The Commissioners have been most patient in their inquiry and have taken the evidence of an immense number of witnesses They have visited all the principal sewage works in the country, have themselves undertaken experiments and have had for some years a large staff of chemists and bacteriologists working upon the theoretical side of the question.

The results of their labours at present have not, I am afraid, justified the hopes of the Government which appointed them. They have, however, done much to assist in the solution of the problem.

One of the main difficulties which Local Authorities were faced with, particularly in the North of England, was the impossibility of obtaining land suitable in quality, quantity, levels and price for irrigation purposes. In an Interim Report published in 1902, the Commission stated that they were satisfied that sewage could be purified to a satisfactory degree by means of certain bacterial systems, and they advised that the Local Government Board requirements of land in every case might with advantage be withdrawn. This advice was adopted and numerous schemes have since been sanctioned in which land for irrigation purposes has not been insisted upon. This was an important step in the right direction.

It was, I believe, in the minds of many Engineers that the Royal Commission would so stereotype the methods of sewage treatment that there would be no matters left for the Consulting Engineer, but this danger to our profession has not yet become apparent nor do I think it likely that it will do so. The Commission in their last Report when dealing with the latest developments of bacterial systems expressly guarded all their conclusions by saying that the circumstances in every case must be carefully considered and that no system of purification was universally applicable.

There are so many variable quantities in the problem, there is such a variety of methods by which purification can be effected, and the number of possible combinations of these is so large, that there is still matter for the Engineer to exercise a sound judgment upon in determining the best process available for any particular town.

In the early days of so-called bacterial systems of sewage purification it was thought that the sludge problem had been solved by the consumption of all solid matters in the sewage by bacterial agencies. Unfortunately this hope has not been fulfilled. A large proportion of the suspended solids may be converted by bacterial agencies into a liquid or gaseous form, but there is still a large residue of mineral and other irreducible matter left over which must be dealt with in the form of sludge. The total quantity, however, is materially reduced, and to a certain extent the difficulty in dealing with the remainder has also been diminished.

We have now arrived at fairly correct data which enable us to design works capable of dealing with sewage of a purely domestic character, and we have further ascertained that most of the liquid tradewastes which are turned into sewers can be dealt with by bacterial processes if the works are suitably designed and the flow of the trade wastes into the sewers is properly regulated so that it is equally spread over the 24 hours and does not reach the works in flushes.

The principal point upon which information is yet required is with regard to the treatment of stormwater. Certain limits have been arrived at as to the quantity of rainwater which should be treated before the surplus can be discharged into streams, but the methods of dealing with combined sewage and stormwater before that degree of dilution has been reached have not been universally successful. Modifications in this part of the process are certain to take place, probably in the direction of treating all stormwater in the same manner as the dry-weather sewage and abandoning the stormwater special works.

The degree of purification necessary, again, has been a subject of controversy, but this obviously must to a certain extent depend upon the nature of the stream into which the effluent is to be ultimately discharged.

Where sewage works send their effluents into a River the water of which is subsequently to be utilised for human consumption, it is obvious that a higher degree of purification should be required than from similar works situated on a large tidal estuary where there are no fisheries.

As to whether or not any of our present systems of purification are sufficiently effectual to purify the sewage of a town and discharge it into a river, the water of which is subsequently used for domestic consumption, is open to doubt. Recent investigations indicate that the effluent from even the best land treatment contains bacteria some of which may be pathogenic, and that the effluent from a bacterial system of purification contains at least an equal number of bacteria.

Under these circumstances it is probable that the future trend of scientific opinion will be in the direction of requiring the effluent from works so situated to be sterilised before being discharged into the river, and the question will then arise as to whether this high degree of purification should be carried out at the expense of the water-consuming community or that of the Authority liable to pollute the stream

Whilst the sewage Engineer is charged with the duty of removing the liquid refuse from the population under his care, an equally important duty devolves upon the Local Authority of removing the solid refuse from the houses of the inhabitants. This refuse like sewage is of an extremely complex nature and contains invariably a large proportion of organic matter which is subject to putrefactive changes which if not arrested will produce nuisance.

The quantity of organic matter in town refuse might be reduced in a very appreciable proportion if householders would recognise the importance of burning in their kitchen fires everything of a combustible nature. There is no reason at all why fish refuse and vegetable matter, like cabbage leaves and potato peelings, should not be burnt on the kitchen fire as soon as produced.

If this were systematically done the refuse finding its way into the ash-bin would consist almost exclusively of ashes and clinker with little or no organic matter present. Such a state of things is, however, impossible in the present stage of our sanitary education and it seems almost hopeless to expect that the public will recognise the importance of this question from a health point of view unless some steps are taken to teach them.

Apart, however, from the refuse removed from private dwellings there is a large quantity of solid refuse from streets, markets, etc., which must be collected and disposed of somehow.

Since the introduction of Refuse Destructors this problem of the disposal of refuse has been largely solved by the cremation process. This is to a large extent a parallel operation to that of sewage purification, the main principle being the oxidation of the organic matter present in the refuse and the production of inorganic and inoffensive residuals.

In the early Destructors the only object in view was the burning of the refuse and the oxidation of organic matter. Owing to the imperfect design of the furnaces the temperatures obtained were not sufficient for the complete combustion of the organic matter and the result was that offensive fumes were found to escape at times from the destructor chimneys. To obviate this what was known as a Fume Cremator was introduced between the furnaces and the chimney.

In the Cremator an ordinary coke fire was kept burning and the products of combustion from the refuse furnaces were conducted through the Cremator and were there subjected to a higher temperature.

The comparatively small quantity of refuse which could be destroyed in furnaces of the older designs led to the introduction of forced draught with the view of increasing the capacity of the furnaces without incurring a larger capital expenditure. The results obtained were highly satisfactory, as the quantity of refuse which could be burnt was doubled and incidentally much higher temperatures were obtained.

The result was that the Fume Cremator was no longer required, as a fire-brick lined combustion chamber between the furnaces and the chimney is sufficient provision for the thorough mixing of all the products of combustion, and if any fumes are given off by a portion of the refuse being consumed, and which has not undergone complete combustion, these fumes on being passed through the combustion chamber are raised to the same high temperature as the remaining products of combustion

The high temperature of the gases passing up the chimneys of the modern Destructors indicated that a waste of heat and power was taking place and boilers were introduced between the combustion chamber and the chimney together with the necessary feed-water heaters and also regenerators for the purpose of heating the air for the forced draught.

By these developments an apparatus has been evolved which will reduce the ordinary town refuse by about two-thirds of its bulk, producing as a residual a highly calcined and vitrified clinker; the whole of the organic matter is completely oxidised and heat is utilised for the production of steam in the proportion of about 1 lb. of steam per lb. of refuse burned.

This steam has been turned to good account in a variety of ways principally in connection with the production of electric current for light and power purposes, and it is also used for pumping, supply of steam to Laundries, Baths, etc., and in other ways.

The residual clinker is utilised for road foundations and filling up low places, and it is worked up into manufactured goods in the form of mortar, concrete, paving flags, bricks, filtering medium for bacteria beds and similar objects.

In addition to the consumption of ordinary town refuse the Destructor is also utilised in a few instances for the reduction of sludge produced in the sewage works.

In these cases a preliminary drying or pressing of the sludge takes place and the partially dried sludge or sludge cake, as the case may be, is then mixed with the ordinary house refuse and is passed through the furnaces. This process reduces the heat available for steam raising and increases the proportion of residual clinker.

The Road question is one of very great importance at the present time. Owing to the rapid introduction of Railways in the middle of the last century the use of the roads as ordinary means of locomotion had largely decreased, and through the abolition of the Turnpike Trusts the quality of roads had seriously depreciated.

The introduction of the bicycle at once brought under notice the uneven surface of the roads and the question again became important. Until the advent of Motor Cars there was no form of transport which brought the unevenness of the roads so prominently before the traveller as the bicycle. Now perhaps the motor car may be said to be equally effective for the purpose. The general effect of bicycle traffic was to require an improvement of the surface of the roads, but it did not do anything towards improving their strength to carry heavy loads.

The more recent development of motor traction, both for rapid light vehicles of the motor-car class and also the slower moving and heavy trade vehicles, has again brought the road question prominently to the front.

The criticism to which Road Engineers are subject is often very exaggerated and very unfair, and those making it frequently display an appalling ignorance of a subject which they do not hesitate to discuss. Only recently, in a series of replies to questions put forward with the view to eliciting opinions from road users, it was suggested that the road of the future must be exposed to sun and wind, and yet have plenty of trees. How these two conditions are to be complied with does not appear to be very obvious. Still, it must be admitted that there is room for improvement in many districts.

There are now two main problems, first the improvement of the road for the motor car itself, which means a smooth surface and a strong road, and secondly the improving of the road for the use of other people, necessitated by the excessive dust and mud produced by motor cars passing at a high rate of speed over existing roads.

These problems are receiving the attention of a host of Road Engineers who are all endeavouring to find the best solution of these questions, which after all are largely financial.

Given an unlimited expenditure, roads can be produced which will be practically perfect from all points of view, but unfortunately the funds are not forthcoming, and the Road Engineer has to squeeze as much money as possible from the Road Authority, and having obtained it must spend it in palliatives rather than in effecting a real cure.

It must be agreed that a large measure of improvement has taken place, and this has been chiefly brought about by using a better quality of stone for the surface material of the carriageways and also by applying various dust preventatives to the surface coverings. These dust preventatives are chiefly of two classes, one, which has for its base coal tar or mineral oil and the other some form of chlorine compound.

These together with tar macadam have been largely used in various parts of the country, but the improvement to be permanent and effective will have to go deeper down and there must be a strengthening of the foundations, especially in many of the country roads, and this can only be done by the expenditure of large sums of money.

Whether or not the motor car users should be specially taxed as a contribution towards this expenditure is a matter for grave consideration. The cost of the roads in this country is a very heavy annual burden, and to add to this burden by heavy expenditure on road foundations would not be a popular policy. Such expenditure should be considered as in the nature of a capital charge, and the Road Authorities should be authorized to raise loans for short periods to carry out works of this character.

As to whether or not the volume of motor traffic is likely to largely increase in the future is open to doubt. As a means of locomotion there can be no question that the motor car is exceedingly useful for journeys up to 50 or even 75 miles. Beyond this radius a train service is usually more rapid.

As the first cost and annual maintenance of motor cars goes down, as it surely will, the motor car will no doubt be more largely used in future for business purposes as a means of transport than at the present time, but on the other hand it is doubtful whether it will ever be used for pleasure or sport more than it is now. At present, however, there appears to be a continual increase in motor-car traffic, and the existing state of the roads is not what it should be to carry it.

As a means of locomotion the Tramway has produced a most marked effect upon the towns of this country within the last fifteen or twenty years.

In the days of the horse tram, and subsequently of steam and cable cars, the tramways existed only in the largest towns and there were used only to a limited extent.

The introduction of electric trams altered the whole position, as this invention placed at our disposal a means of transport sufficiently rapid and economical to encourage cheap fares and long journeys in comparatively reasonable time.

The result of this has been that the suburbs of large towns have been brought within the reach of those classes of the population which could not afford either the time or money to travel by the older means of locomotion. This development has been an unmixed blessing as it has enabled the workers of the community to live further away from the factories, in districts where land is not too costly to allow of proper air space being provided round the dwelling houses.

The overhead trolley system has been so largely adopted that it has, I think, proved its superiority over every other system. It is true that in London and a few other places the conduit system has been applied, but this is only possible where the traffic is so heavy that the extra capital expenditure involved is fully warranted. This is a condition which does not prevail in most instances, and the only other alternative is a contact system, which apparently does not find favour owing to its complication and the practical impossibility of reducing to reasonable limits the loss of current by leakage.

The success or otherwise of a tramway system depends very largely upon the population making use of it. In large towns tramway services invariably are successful from a pecuniary point of view, and the fares charged are lower than by any other means of locomotion.

On the other hand, where the population is too restricted to fully occupy the car service it is necessary to charge higher fares, and even then the result from a financial point of view is not always satisfactory and it then becomes a question whether the service cannot be better met by running Motor Omnibuses or in some other way, but in considering this question the cost of road maintenance must be fully considered.

Probably a population of 30,000 and a car service of 20 minutes may be considered as the inferior limits below which a tram service cannot be financially successful.

The effect of the competition of tramways upon the local traffic of railways has doubtless been very marked, and in several instances which have come within my notice the Railway Companies have recognised that in order to compete successfully with the Tramway services they must be prepared to improve their own methods by adding to the number of trains and also by reducing their fares to meet those charged by the competing company.

This competition, however, is to a large extent controlled by the time occupied on the journey, and a distance of five miles may probably be taken as the limit over which a tram service can compete with railways, and therefore for an inter-town service the centres of population should not be more than ten miles distant from one another. When the distance becomes greater than this the time occupied on the tram journey by the passenger becomes of such importance that he will take train even at considerable inconvenience rather than spend so much time in travelling.

The question whether or not the Tramway service should be in the hands of the Local Authority or in those of a company, is, I think, open to very little doubt. The road authority should have control over everything which affects the roads, and particularly the Tramway service.

In many instances friction has arisen through the dual control of the surface of the roads where Companies have laid Tramways, and particularly in cases where they have proceeded under the Light Railways Act, which was never intended to facilitate the construction of Tramways for passenger service along public roads.

The Tramway Company feel that it is no part of their duty to widen and improve the highways and streets of a town, and that they have a sufficient burden placed on them by the ordinary paving round the track, whereas the Local Authority take up the position that the introduction of large and unwieldy vehicles such as tramcars in their highways is a cause of increased pressure upon the road space, and that consequently they are entitled to expect the Tramway Company to bear their share of the cost of road improvements and widenings as well as to maintain the surface.

Further difficulty arises in the liability to keep in repair the macadam portion of the road immediately adjoining the paved margins of a tram track. This is a point at which excessive wear takes place and it is doubtless brought about by the existence of a paved margin. The Local Authority object to the extra cost so thrust upon them, whilst often the Tramway Company feel that even with this extra cost the road authority are still escaping a good deal of their previous expenditure.

The large introduction of motor omnibuses and the suggested trackless tramcars tends to complicate the question of public conveyances along our streets and roads. Motor omnibuses are usually provided and run by private owners who, except as ordinary ratepayers, do not contribute in any special degree to the road maintenance, yet these motor omnibuses cause a tremendous amount of wear and tear on the roads over which they travel.

This fact must always be borne in mind when comparing the cost of transport by various methods. The cost per mile run by motor omnibus, or per head of the passengers carried, may be less than similar figures obtained by tramway services, but the cost of keeping in repair the roads traversed by the motor omnibuses does not appear in the account at all, but falls upon the general rates of the district.

The time at my disposal precludes my touching upon many other important topics of equal interest in relation to Municipal Works. The subject is a large one, and I have been able only to give you a very brief review of some of its salient features ; to have attempted to consider it in detail would have been beyond the scope of an Address such as this. In concluding, I must thank you for the patience with which you have listened to me.

Mr. Percy Griffith : Gentlemen, it is sometimes asked why a Past-President continues to devote himself to the interests of the Society ; and if a selfish motive were required, I suggest that it is the opportunity of occasionally getting up and criticising a junior president upon his address. He gets the additional privilege of being entitled to speak without being called upon from the Chair, and further of being able to make remarks which cannot be refuted ; there is, therefore, some advantage in occupying the position I now take as the senior past-president available for the interesting and pleasant duty of dealing with the Presidential Address. Needless to say, I shall ask you to express your feelings regarding the address, and the nature of those feelings I will leave to the last.

A few remarks are, I think, justified upon the very interesting address to which we have listened, and I am quite confident when I say that our President is so familiar with the subjects which he has brought before us to-night, that he had far less labour in writing his paper than he has had in reading it.

The first five pages of the address, or the fourth part of the whole, is devoted to our domestic concerns. In regard to that I only wish to say that he has with him a very unanimous and enthusiastic Council, and all that he has said of the work of the Society would be echoed by every member of the Council ; he has, in fact, spoken on behalf of the Council as well as on his own behalf.

But the main subject of this interesting address has been, as you know, municipal engineering ; and while I am not in this case permitted to be critical, I cannot help remarking that the President has commented very favourably upon the position and work of a municipal engineer, while, as a matter of fact, that position is one that he has left. Well, no doubt the President knows from experience what it is like to be a municipal engineer, but I presume we must not take it that he gave it up because he did not like it.

The President has given us something better than a resumé of municipal engineering, because he has really confined himself to its most interesting and up-to-date features. One might wish that the President would, on some occasion when we could discuss the matter, introduce again the much debated subject of municipal control. Guarded as he has been throughout this address, he has " let himself go " in connection with two subjects : viz., water supply and tramways. There would be, I am quite sure, in this Society a good deal of interesting discussion upon both those subjects with regard to municipal control. But I am not entitled to raise a discussion at the present time, and I only mention the point because I feel sure that all has not been said that might be said upon this very interesting subject. While I note with interest the views of our President upon those subjects, I think that some of us are not altogether converted to his point of view, and we are, perhaps, a little keen " to have it out " with him

But now generally with regard to the address, it were easy indeed to be flattering, but to spare your time, and because I know that you agree with me, I will not dilate on that particular point. The strongest point of the address is that the President has dealt with those branches of municipal engineering which are of particular interest at the present time, because of recent developments. He has given us the actual nature of those developments, and, therefore, to many of us he has given much instructive as well as interesting matter.

One other feature of the Address is the revelation of the varied nature of the President's experience as a municipal engineer, and, I am quite sure, this experience has been extended by his work since he left that position. It is a great advantage to us to have a President of large and varied experience, because our Society is unique in representing every branch of this large and important profession of engineering. A President with such a large experience as Mr. Silcock has had must be efficiently equipped to control the work of the Society, which, as you know, is now being very rapidly developed. In these respects, and in many others which I have not mentioned, I am sure those of you present will agree with me that this address deserves our most cordial and hearty thanks, and I have the greatest pleasure, and feel greatly the honour of being called upon to propose that a very hearty vote of thanks be accorded to the President for his address.

Mr. Arthur Valon : Gentlemen, Mr. Percy Griffith, in proposing this vote of thanks, claimed it as a privilege of a past-president to take this opportunity to comment upon an address which otherwise it would be impossible to comment upon. Not being a past-president I cannot claim that privilege. I can only say that the address to which we have had the pleasure of listening bears the obvious imprint of ripe judgment and wide experience, and I am quite sure you will agree that our thanks are due to our President for the large amount of time and care that he must have expended in its preparation, and for the generous way in which he has laid before us the opinions that he has formed from a large practice during a long professional career. I have very much pleasure in seconding this vote of thanks.

The vote was then carried by acclamation.

The President : Mr. Griffith, Mr. Valon, and gentlemen, I am exceedingly obliged to you for the flattering way in which you have proposed this vote of thanks, and the manner in which the meeting has received it. I can assure you that the preparation of a Presidential address is not the easy task which Mr. Griffith appeared to think I should find it. The difficulty which presented itself most to my mind was the selection of the matter on which to address you, because, as I said at the conclusion of my remarks, it is a very big subject, and I could only select a few of the more important matters on which to speak to you.

Gentlemen, I beg to thank you very much for the kind way in which you have received this address.

March 1*st,* 1909.

EDWARD JOHN SILCOCK, President,

in the Chair.

A NEW TEST FOR CONCRETE,

By J. S. Owens, B.A., M.D., A.M.Inst.C.E., F.R.G.S., M.R.S.I.

It is customary in specifications for works in which concrete is used to state clearly the tests which the cement must satisfy. Similarly the exact nature and proportions of the aggregate are laid down, and the method of mixing which is to be used. It will therefore be seen that, while the nature of the actual material is clearly specified in the case of each of the separate ingredients to be used, only the method of arriving at a certain result is specified in the case of the concrete itself. In other words, while the nature and quantity of each ingredient are carefully specified, the quality of the resulting concrete, which depends upon thorough mixing, is not thereby assured.

It therefore appears that there is here a weakness in our specifications which may entirely nullify the effects of the care otherwise displayed in drawing them up. Reasoning along such lines as these the Author was led to devote his attention to devising a test which could be applied to concrete on the works ; and which would enable the engineer to satisfy himself that the mixing was being carried out efficiently.

The methods of determining when concrete has been properly mixed, which have been used up to the present, are as follows :—Inspection of the mass. ' This is at best only a very crude method and, as will be shown in this paper, ineffective. It is impossible by inspection alone to tell the difference in the appearance of concrete composed of one part of cement to two of ballast, and concrete having one part of cement to three of ballast. The even distribution of the water can, however, be easily recognised by inspection alone, owing to the uniform stiffness of the mass.

Another method, which is sound in principle, is to make briquettes of the concrete and break them after say seven days ; thorough mixing will be indicated by uniformity of breaking stress. This can hardly be regarded as a works test, and suffers from the drawback that considerable time must elapse before the result is known. It would be difficult, for example, for a clerk of works to suspend concreting operations for the week or so necessary to get a result by this means.

Again, pigment has been added to the concrete to test the mixing. Briquettes were made, allowed to set, and broken the fractured surfaces being examined for even distribution of the pigment. This is very ingenious, but clearly is not applicable to testing concrete on the works; where pigment could not be added. It has also the same disadvantage as the previous test, in addition to the difficulty of telling by mere inspection whether the pigment is evenly mixed with the concrete.

When Mr. Taylor was designing his well known concrete mixer he adopted a novel method of testing it. The drum of the mixer was made of glass, and layers of coloured beads were placed in the bottom. He then noted the number of revolutions necessary to mix the beads until there were as many of one colour as of another in a given area of surface. This method is of course useless for concrete, nor indeed could the beads give any indication as to the amount of mixing which concrete would require. Probably the only use to which it could be put would be to compare the relative mixing power of different arrangements of drum or deflectors.

In the Author's opinion, too little attention has been given by engineers to the question of concrete mixing; especially in view of the enormous strides which have been made of recent years in the application of concrete reinforced with steel. Not only is there more concrete used now than there was some years ago, but the protection of the steel reinforcements calls for a greater exercise of care in the making.

Perhaps the simplest definition of properly mixed concrete would be :—Concrete in which the various ingredients are as uniformly distributed as the size of the particles composing them will admit. Until this uniformity of distribution has been attained the mixing process must be regarded as incomplete. On the other hand, when a uniform mortar has been formed of the sand, cement and water, and the particles of stone or gravel have been spread evenly through this mortar, we may say that mixture is complete. The question, therefore, is how to determine when this uniformity of distribution has been attained.

If we take a few small samples from different parts of a heap of concrete, and if we can tell in some simple way whether all the samples contain the same relative proportions of stone, sand and cement, we have a means of telling whether the concrete is properly mixed or not. When the mixture is complete, all the samples will, if of the same size, contain the same amount of the respective ingredients.

A knowledge of the different rates of settlement, in water, of materials composed of different sized particles, of the same sp. gr., suggested that this peculiarity might be utilised to separate rapidly the ingredients composing concrete; and a series of experiments, the results of which are given in this paper, was undertaken to determine the practical value of the method.

It was found that when a sample of concrete, freshly mixed, was placed in a tall, narrow glass vessel nearly full of water, and shaken up, on standing, the cement, sand and stone settled at very different rates. The large stones collected at the bottom ; over them, and clearly defined, came a layer of sand ; and over the sand a layer of cement ; the lines of demarcation being perfectly distinct. The next question was to determine whether the thickness of these layers was directly proportional to the amount of material present in the sample ; if so, here was a method of telling at once whether each sample contained the same proportions. It was not essential to know the exact amount of material present in each layer, but simply whether the relative proportions were the same in each sample.

The success of this method of separation depends on the fact that the rate of settlement of particles in water, if of the same specific gravity, is governed by their size. To bring out the difference in the rate of settlement, a tall vessel is necessary, since the object is to make the time interval between the arrival of the various sized particles at the bottom as great as possible.

For particles over 0·0039 in. in diameter, the velocity of fall in water is given by the following formula :—

Where v represents the velocity in ft. per sec.
d represents the diameter of particle in ft.
s represents the sp. gr. of the particle.
then v is equal to $4{\cdot}3 \sqrt{d(s-1)}$

This is the law which governs the settlement of the sand ; that is, the velocity of descent varies as the square root of the diameter of the grain. When, however, the diameter falls below 0·0039 in. the viscosity of the liquid controls the rate of settlement ; and it then varies as the square of the diameter.

The British Standard Specification for cement states that it must not give a residue exceeding 18 % on a sieve having 32,400 meshes per square inch. These meshes are 1/180 of an inch square, and the wire forming the sieve is 0·002 of an inch in diameter ; 1/180 of an inch is approximately 0·0056, and if we deduct from this the diameter of the wire, 0·002, it gives us 0·0036 of an inch as the size of the actual openings, and hence of the largest grain which will pass through. Particles of cement are therefore usually under 0·0039 of an inch in diameter, and consequently do not even obey the same law which governs the deposit of sand. For example : In a tube 18 inches high and 1in. diameter, the settlement of the sand, even the finest particles, was complete in about 10 seconds, whereas the cement took 5 to 10 minutes to deposit ; thus the sand sank over 30 times as fast as the cement.

The way in which the concrete deposits in the test glass is curious. On shaking up a sample with water in a tube and placing to settle, the large particles of gravel sank to the bottom immediately, to be followed by the sand in five or ten seconds, but the cement behaved in a different way. The first effect was always a clearing of the top of the water, and the formation of an ill-defined, cloudy line of junction between the clear water and that containing the cement. In perhaps five minutes this line of junction, which was descending slowly, altered in appearance almost suddenly, and showed a clear, well defined surface. On measuring the depth of the layer of cement at this stage it was found that it was still shrinking very slowly ; but when measured at intervals of two or three minutes it was noticed that after a short time, perhaps 10 or 15 minutes, a minimum thickness was reached, and no further contraction took place. This was clearly the time at which to take a final measurement, and it was found that the thickness of the layer depended, other things being equal, on the amount of cement present in the sample. Provided therefore that the minimum thickness of cement layer is taken, it is not essential that the time of settlement should be exactly the same, when it is desired to compare two samples.

It was found, however, that the thickness of the cement layer depended somewhat on the time which had elapsed since wetting ; and in tubes which had been allowed to settle and then shaken up again, each time that this was repeated gave a thicker layer of sediment than before ; owing doubtless to the reaction between the cement and water. This is shown in experiment (4). It is therefore clear that comparison as to the amount of cement present can only be made by this method when the samples are from the same mixing. A few minutes more exposure in one sample than in another will, however, make little difference.

This effect of the thickening of the layer of sediment appears to depend somewhat also on the nature of the cement used, some cements being more sensitive than others in this respect. If the process of shaking up and standing be repeated often enough, the surface will eventually fail to become sharp, however long the test glass may stand ; the sediment will become flocculent, and the surface ill defined.

If too small a quantity of water be used to shake up the concrete with, another error of some importance is introduced. When the tube is placed to settle, the sand and gravel at the bottom entangles a certain amount of cement, and the less the quantity of water used the more cement will be thus entangled, owing to the mixture of cement and water being more concentrated. When the total height of the column of water and concrete was about twice that of the concrete alone, the amount entangled in the sand was about 35 % ; when, however, a water column of about four times the height of the concrete in the tube was used the amount of cement caught in the sand layer was negligible. The effect of this is shown in experiments 5 and 6.

A curious effect was noticed when the tubes were placed to settle exposed to sunlight. The layer of cement on settlement was not level, but inclined downwards from the sunny side. The cause of this was that in each tube an ascending current was formed on the sunny side and a descending one on the other, the change of direction occurring on the bottom, over the surface of the cement layer, where a distinct current setting towards the sunny side therefore existed ; and this carried the suspended particles with it and piled them up on that side. The direction of the currents could be seen from the movements of these particles, and the amount of tilting of the layer amounted to about one in ten.

Some experiments bearing on the test and showing the errors to be guarded against will now be described, together with the inferences which the Author has drawn from them.

Experiment (1).—This compares the thickness of the layers formed from 1, 2 and 3 measures of cement respectively, when placed to settle in tubes of the same size.

The tubes used were ¾ inch diameter and 6 inches long, the water column being 4 inches high.

The tube containing one measure of cement, on shaking up and allowing to settle, gave a layer of sediment ½ inch thick after three minutes ; no further contraction after this. That containing two measures gave a layer 1 inch thick after four minutes, after which no further contraction took place. The tube having three measures gave a layer 1½ inches thick after six minutes, when contraction ceased.

The thickness of the layer of sediment was in each case, therefore, proportional to the amount of cement present ; and the greater the quantity the longer time was required for complete settlement.

Experiment (2).—In this, samples of concrete were made containing various proportions of cement and sand. These were shaken up in tubes 1 inch diameter and 18 inches long, with about 12 inches of water column ; care being taken that each tube received exactly the same amount by measure. The tubes were then placed to settle. If the test was accurately carried out, and the concrete well mixed, each sample should give layers of cement and sand having a thickness approximately proportional to the amount of each contained in the concrete. To find this amount the shrinkage of the concrete had to be measured and taken into account. The sand used was of nearly uniform grain, and it was found that by adding one part by measure of cement to one of sand, on mixing and wetting, the resulting concrete occupied only one and one-sixth measure. On adding one of cement to two of sand, the concrete occupied approximately two measures. The concrete therefore of one to two, and weaker strength, occupied the same bulk as the sand used in making it. This is brought out also in the results of the experiment, in which the sand layers in the last three are seen to be of the same thickness. The results are shown in Table I.

TABLE I.

Concrete composed by measure of	Amount of Concrete resulting from mixture in same measures.	Thickness of Sand layer in inches.	Thickness of Cement layer in inches.	Relative thickness of Cement layers in each tube.	Relative amount of Cement in the Concrete placed in each tube.	Time of settlement of Cement in minutes.	Time of settlement of Sand.
Sand 1 Cement 1	$1\frac{1}{6}$	0·85	1·15	1·00	1·00	5	About 10 seconds each.
Sand 2 Cement 1	2	1·00	0·60	0·52	0·58	5	
Sand 3 Cement 1	3	1·00	0·50	0·43	0·39	5	
Sand 4 Cement 1	4	1·00	0·35	0·30	0·29	5	

Experiment (3).—Compares the layers of cement sediment formed when one measure of cement was shaken up with 1 ; 2 ; 3 and 4 measures of sand. Each tube had water added to a height of 16 inches, and was then shaken with the sand and cement and allowed to settle. Each tube gave a layer of cement sediment of one inch in thickness, although the sand layer varied with the amount present from about three-quarters to three inches.

This shows that the amount of cement entangled by the sand was too small to affect the result, and that the cement layers were strictly proportional to the amount present.

Experiment (4).—Shows the increase in thickness of the cement layer deposited from the same quantity of cement, when the time of exposure to the water was prolonged. The tubes used were 1 inch in diameter and 18 inches long, the water column being 12 inches high. Before adding the water, 1 inch of sand and $\frac{1}{2}$ inch of cement were placed in the tube dry. The water was then added, the tubes shaken, and allowed to stand. The sand settled to a layer 1·1 inch thick and the cement to 0·80 inch, which increased as follows :—

Placed to settle.	*Minimum thickness.*	*Reached at*
10.33 a.m.	0·80 inch	10.40 a.m.
Shaken up again 10.45 a.m. ..	0·80 ,,	10.57 a.m.
Shaken up again 11.40 a.m. ..	0·95 ,, ..	12.2 a.m.

There was therefore no apparent expansion of the cement layer in this case after 12 minutes' exposure to the water, but after about an hour it was distinct.

Experiment (5).—To determine the effect of the entanglement of the cement in the sand layer upon the validity of the test. One measure of cement was added to about six of coarse sand in a similar tube to that used in the last experiment ; water was added to a height of 7 inches above the sand and cement, and the tube shaken up and placed to settle. The coarse particles formed a layer on the bottom, then came the finer sand about 3½ inches in all, and on top the cement layer. The latter was 0·7 inch thick, and a slight amount of cement could be seen in the sand. This was then washed out by means of a small glass tube discharging water, and on settling again the layer was 0·7 inch thick ; showing the effect of the sand carrying down cement with it to be inappreciable. To further elucidate this point the following experiment was then made.

Experiment (6).—Two tubes were taken, 18 inches by 1 inch, into each was put the same amount of sand and cement ; the cement in this case being weighed, but the sand was not measured accurately, enough being put in to give a column about three inches high in the tube. One tube was then shaken up with enough water to make with the sand and cement a column 7 inches high. The other had, at first, only a small quantity of water added, with which it was shaken and then a small glass tube was inserted to the bottom and water discharged through the sand and cement till all the cement was washed out of the sand. It was found that the latter gave a layer of cement on settlement 1·3 inch thick, whereas the former gave only a 0·85 inch layer. Thus there was a considerable inaccuracy due to the amount of cement held by the sand in this case.

The experiment was repeated exactly as before, with this exception ; the first tube had a column of water 16 inches high instead of 7. In this case both tubes gave a layer of cement exactly the same thickness. Thus, to eliminate error, a water column of at least four times the height of the sand and cement column should be used.

Experiment (7).—To determine the effect of the temperature of the water on the thickness of the cement layer, two measures of sand and one of cement were mixed and added to water in an 18-inch by 1-inch tube, shaken up for half a minute and allowed to settle. This was repeated at different temperatures with fresh cement, the same amount of water being used and the tube shaken for the same time before standing each time. The temperature ot the water was taken on settlement. The results are given below :

Temp. °F.	63	64·2	67·6	69·3	70·3	72·0	75·3	79	87
Cement layer	0·70	0·78	0·83	0·83	0·90	0·95	1·0	0·9	0·7

These figures when plotted give a practically regular curve having a maximum at 75 degrees F. It would seem that while the chemical change, which is doubtless responsible for the increase in the thickness of the cement layer, is hurried on by the rise of temperature, the increased rapidity of settlement due to the rise had an equal counterbalancing effect at about 87° F. The time required to settle at the latter temperature was only 3 minutes, whereas at 69° it was nearly 6 minutes. The variation in rate of settlement due to change of temperature is considerable, and is stated by Mr. A. Hazen* to be proportional to $\frac{t + 10}{60}$ t being the temperature of the water in degrees F.

Again: 60 grains of cement in water at 61° F. formed a layer 0·55 inch thick, and at 69°, 0·69 inch; 80 grains in water at 61·5° F. formed a layer 0·80, and at 67° F., 1·00 inch thick.

Experiment (8).—In order to find what are the limits of accuracy to be attained by mere inspection as a test of thorough mixing, the following experiment was made. The question to be answered is really :—What is the smallest variation in the proportions of concrete which can be detected by inspection alone? To answer this, concrete was made containing sand 2 parts and cement 1, and mixed with water. Further samples were then made with slightly different proportions of cement and sand, and the smallest amount of variation which could be detected by inspection alone noted. The proportions were by measure and the results as follows :—On comparing concrete having sand 2, cement 1, with some having sand 2½ and cement 1, no difference could be detected. The result was the same when it was compared with a sample with sand 3 and cement 1, and it was only when the proportion of sand was increased to 3½ that a difference could with any certainty be noticed; and even then it was very slight. It is clear from this that we cannot tell by eye whether one part of a heap of concrete contains more sand in proportion to cement than another, unless the difference be comparatively great. One part of the heap might be rich in cement and another poor and yet it would not be apparent to the eye. Speaking generally, the strength of concrete structures may be taken as that of their weakest part; as that of a chain is measured by its weakest link; hence the necessity for making sure that the ingredients are perfectly uniformly distributed throughout the concrete.

On applying the sedimentation test to the same samples it was found that the difference between the concrete composed of sand 2, cement 1, and that of sand 2½, cement 1, was quite distinct. The former gave layers of sand and cement 1·0 and 0·5 inch thick respectively; and the latter layers 1·03 and 0·36 inch thick. The ratio of cement to sand layer being respectively 0·50 and 0·35.

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* Trans. Amer. Soc. Civ. Eng., Vol. LIII.

To determine the effect of the alteration in volume of the cement or sand on settlement when compared with the volume dry, which is used in measuring for concrete :—

Let S equal unit volume of sand when dry.

Let C equal unit volume of cement when dry.

Let $S \times n$, equal volume on settlement of the sand.

Let $C \times m$, equal volume on settlement of the cement.

Let the samples of concrete contain S sand and C cement.
S^1 sand and C^1 cement, etc.

The mixture will be uniform when $\frac{S}{C}$ equals $\frac{S^1}{C^1}$ etc.

Consider the effect when the samples are of equal volume. Then, when mixture is complete, each will contain the same amount of sand and of cement. But what we measure is $S \times n$ and $C \times m$, and $S \times n$ will be equal to $S^1 \times n$; and $C \times m$ to $C^1 \times m$. Or the sand and cement layers from one sample equal to the sand and cement from the other respectively.

If the samples are of different size :—Let $S + C$ be equal to $y\,(S^1 + C^1)$. Then $S + C$ will be equal to $y\,S^1 + y\,C^1$, and when the sand has the same ratio to the cement layer in each, $\frac{S\,n}{C\,m}$ will be equal to $\frac{y\,S^1\,n}{y\,C^1\,m}$, and $\frac{S}{C}$ to $\frac{S^1}{C^1}$ and the mixture will be uniform.

The validity of this reasoning depends on n and m remaining constant for different depths of sand and cement. In the case of the former, the depth of a layer of dry, or nearly dry, sand was compared with the depth of the same sand on shaking up with water and allowing to settle ; with the result that, although slight differences were apparent, due probably to the amount of moisture present on making the "dry" measurement, it was found that the sand when dry occupied the same volume as after settlement ; as, indeed, was to be expected. In this case therefore n is equal to 1 and constant.

To determine the relation of the dry measure of cement to the volume on settlement, the following experiment was made :

Experiment (9).—Into a tube one inch in diameter 1 ; 2 ; 3 and 4 measures of cement were put successively, shaken up with about a 13-inch column of water for 15 seconds each, and allowed to settle. The depths of the layers of sediment should be in the ratio of 1 ; 2 ; 3 and 4 if m is constant.

The result of this was as shown in Table II.

TABLE II.

Measures of Cement.	Equivalent depth of dry layer 1 in. dia. Inches.	Layer of Cement after settlement. Inches.	Temp. of Water °F.	Time of settlement in minutes.	Ratio of thickness of layers.	(*m*) or Ratio of wet to dry layer $\frac{W}{D}$
1	0·47	0·60	57	5	1·00	1·28
2	0·94	1·17	58	10	1·95	1·25
3	1·41	1·74	59·5	12	2·90	1·23
4	1·88	2·35	61	20	3·92	1·25

It will be seen from this that *m* is constant, or practically so, although there is a tendency for it to be reduced as the thickness of the layer of sediment increases. There is therefore nothing in this to invalidate the test, especially as any variation in *m* would only affect the results when the samples used are of different volume. When therefore reasonable care is taken to obtain samples of the same size, any slight variation in *m* will have no injurious result.

It must be remembered that there is probably an error in observation of plus or minus 0·02 of an inch; and, since the cement was measured, there would be also a probability of a slight variation in the contents of the measure owing to different pressure being used in filling; but the result is accurate enough for the purpose.

Passing on now to the application of the test in practice:—The strength of concrete depends practically entirely upon that of the mortar which cements the larger particles of stone together. That being so, we may look at the question of proportions in this way:—The ratio of cement to sand used will be determined by the strength of the concrete required, and the amount of coarser particles of stone or gravel which may be added will be the largest quantity which permits of complete separation of the individual particles by the mortar. In other words, there must be a little more mortar than will completely fill the voids in the stone or gravel; and any increase over the amount necessary to do this does not mean an improvement in the strength or impermeability of the concrete. We come therefore to the conclusion that it is the mortar which, other things being equal, determines the strength of the concrete.

Now it is a well known fact that to mix mortar effectively requires more work than to mix concrete containing coarser particles. A mixer which is working on cement mortar cannot turn out so great a quantity as when the machine is working on concrete. It is therefore obvious that if, when mixing concrete, it can be shown that the sand and cement are thoroughly mixed together, we may feel sure that the coarser particles are properly distributed throughout the mass. The importance of this is that it removes a difficulty in the practical carrying out of the test, since it is unnecessary to measure the amount of coarse particles of stone in a sample if we can measure the sand and cement. If therefore the samples contain slightly different amounts of mortar, as may happen if we include the coarse particles in taking them, this will not affect a conclusion drawn from the relative amount of sand and cement present in each. Again we may entirely remove the stones from our sample, as is convenient in dealing with concrete having a coarse aggregate, and test the mortar only, knowing that if it is well mixed the concrete is well mixed.

It is desirable that the samples taken for the purpose of the test should be of the same volume, as nearly as possible, although it is not essential that they should be exactly the same, since the only thing necessary to show that a perfectly uniform mixture has been attained is that the ratio of the thickness of the sand to the cement layer should be the same for each sample. It is difficult, with a material such as concrete, to fill a small measure so as to be certain that each time you have exactly the same volume of mortar present ; since the inclusion of a large stone more or less may make a difference in the amount of mortar contained. It would therefore be impossible to be certain that a slight inequality in the actual thickness of sand and cement in one sample, as compared with sand and cement respectively in the other, meant that mixing was incomplete. We can, however, be sure that inequality in the ratio of sand to cement in one to the same ratio in the other means incomplete mixture ; and conversely, that equality of these ratios means complete mixture.

In making an actual test of concrete, although the entire sample may be placed in the test glass, and shaken with water, it was found preferable to separate out the coarse particles of stone before applying the settlement test. When the aggregate contains stones up to two inches in diameter there is danger of breaking the glass in introducing the sample and shaking it ; and further, the glass becomes cumbersome owing to the large size required. Again, although the large stones sink to the bottom before the sand, unless there is enough sand in the sample to entirely fill the voids between the stones, it does not settle with a clearly defined upper surface, but trickles down between the stones, and leaves an irregular surface on the top.

The method adopted in the case of concrete having stones up to $\frac{3}{4}$ inch in diameter was as follows :—Two test glasses were used, having a diameter of 1·5 inch and a height of 13 inches ; a funnel fitting into the top of the glasses was provided, and a conical wire screen fitting into the funnel ; the screen had meshes about one-twelfth of an inch square, or 144 to the square inch. Two samples were taken in a small tin measure, containing 6·2 cubic inches, each being taken from a different part of the heap of concrete under test. The funnel with its screen having been placed over a test glass, a sample was emptied into the funnel, care being taken to wash out the last particle from the measure. A small stream of water was then allowed to trickle through the concrete, which was stirred vigorously meanwhile, with the result that all the cement and fine sand were washed through the wire screen into the test glass, and in about a minute the coarse stones were left perfectly clean in the funnel. These were thrown away, or retained for measurement if desired ; and the test glass, having been filled to within about an inch of the top with water, was shaken up and placed to settle. The sand commenced to fall immediately and was all down in a few seconds, leaving the cement in suspension in the water, the cement then gradually settled down, and in about 10 minutes reached a layer of minimum thickness. The depth of the sand and cement in each glass was then measured.

In testing concrete having stones up to two inches in diameter it is best, as suggested before, to remove the large stones from the sample, and use only the mortar for the test.

The test as described may be applied to determine whether concrete contains the specified proportions or not ; it will, however, be better as a rule to determine this from a measurement of the gauge boxes combined with a mixing test. A fair idea on this point may be obtained as follows :—Prepare a sample of concrete having the specified proportions, and mix thoroughly, taking care that it is made from the same materials and wet at the same time as the concrete it is desired to test the proportions of. A sample of the latter may then be tested against the specially prepared sample, and if the sand and cement differ materially in each, we may infer that there is a difference also in the proportions present. It is difficult, however, in a small sample to tell much about the proportion of stone or gravel present ; and it must be noted that for the purpose of testing the mixing, the smaller the sample which can be conveniently used the more accurate is the result ; whereas in dealing with the proportions, the larger the sample the better. In the example which follows, each test was made with a different charge of materials in the machine, and it will be observed that the sand and cement layers differ materially in thickness in the different samples, showing that the proportions were not being accurately maintained. The chief cause of this lay in the measurement of the sand, which was somewhat falsified by the fact that the proportion present in the ballast used varied.

Up to the present the test has been applied practically to only one concrete mixer, and particulars of this are given. No attempt is made here to compare this machine with others on the market, but the results are given because they bring out one of the uses to which such a test may be applied.

The machine tested was in operation preparing concrete for a large ferro-concrete building. This machine was of the rotary drum type, and had fixed on the internal surface of the drum a peculiar arrangement of deflectors, which had the double effect of ploughing through the material lying on the bottom of the drum and of lifting part of it to the top, from where it was discharged as a shower on that below. A fixed hopper was provided, which received the dry materials, and discharged them into the mixing drum, when a gate connecting the hopper and drum was opened. Water was supplied when the hopper had emptied, the whole operation going on while the machine was running. The discharge was into wheelbarrows, three of which were required to one charge. Only one man was employed attending to the machine. The drum had a capacity of 5 cu. ft. and ran at 18 revs. per min., the output as per maker's list was 50 yds. cub. per 10 hrs.

The concrete was composed of gravel 4, sand 2 cu. ft. and 100 lbs. of cement. The largest particle of gravel would pass a $\frac{3}{4}$ inch ring. The method of carrying out the test was as just described, and the results were as shown in Table III.

TABLE III.

Time required to empty feed hopper into drum. Seconds.	Time of mixing after whole charge was in drum. Seconds.	Thickness of Layers.				Ratio $\frac{S}{C}$	Ratio $\frac{S}{C}$	Time of Discharge.
		Sand.		Cement.				
		Tube 1.	Tube 2.	Tube 1.	Tube 2.	Tube 1.	Tube 2.	
30	—	1·2	1·2	2·0	2·2	0·60	0·55	Six seconds per barrow, or one-third of a charge.
20	10	1·0	1·0	1·7	1·9	0·59	0·53	
25	20	1·3	1·3	1·9	1·9	0·68	0·68	
30	30	1·0	1·0	1·8	1·8	0·55	0·55	
25	35	1·4	1·4	1·9	1·9	0·74	0·74	

The mixture in this case was uniform 20 seconds after the charge was in the drum. It must, however, be noted that the feed hopper took an average of 26 seconds to empty, during which time the mixing of that part of the charge which had entered the drum was going on. Putting the time of discharge as 20 seconds, it will be seen that the whole operation of feeding, mixing, and discharging need occupy only 66 seconds. This is assuming that discharge takes place as soon as the mixture is complete ; but this was not the case in the present instance, since the concrete could not be used as fast as the machine could turn it out. If worked to its full capacity, it could therefore mix 101 yds. c. in 10 hrs., which is double the amount it was rated for. It is obvious, however, that it would be impossible for one man to feed 101 yds. to the machine in 10 hours ; hence to get the maximum capacity more attendants would be required.

It appeared to the Author that it would be interesting if some tests could also be made on hand-mixed concrete ; as he has long been of the opinion that a perfectly uniform mixture is very seldom obtained by this method. Arrangements were therefore made to carry out a few tests of such concrete on works where mixing was done by hand. Seven such tests were made, all on works in or near London ; in every case the concrete was carefully mixed, probably more carefully than usual in the first four cases, owing to the presence of the foreman or engineer for the works beside the banker ; and the fact, which must have been obvious to the men, that some test was to be made. In the fifth test, however, the men were not aware that the concrete would be tested, as on the Author's arrival he found a heap of concrete ready mixed for the work ; it had been turned twice dry and twice wet, and from this samples were taken. Numbers (6) and (7) are from concrete turned twice dry and twice wet, mixed in the Author's presence.

The results are given in Table IV. The glasses used for settlement were 13 inches high by 1½in. diameter.

It will be seen that uniformity of mixture was attained in only one case, although the concrete looked well mixed. This shows, not only the impossibility of determining when mixture is complete by eye alone, but also the difficulty of getting the best results with hand-mixed concrete. Test (5) brings out the effect of the human element ; as in this, which was the only one of concrete made without close supervision, the variation in the amount of cement in different parts of the concrete was as much as 24 %.

It is unnecessary to point out to engineers what this means, and the waste of material which it implies.

To summarise :—The Author hopes this test will be of value in enabling engineers to determine whether concrete is being properly mixed or not in any particular case ; and in relation to mixing machines, to fix the time necessary for any machine to produce a proper mixture, and thus to determine its legitimate output of well mixed concrete.

The precautions to be observed in making a test are as follows :—Two or three test glasses of sufficient diameter should be used, one for each sample. The same glass must not be used for each sample, as the time of exposure to water and the temperature of the water might be different in each test.

A column of water at least four times the height of the layer

TABLE IV:

Date. 1908.	No. of test.	Proportions—Ballast, Sand, Cement.	Size of Sample. Cubic inches.	Sand layer in inches.		Cement layer in inches.		Ratio: Sand layer. / Cement layer.		Per cent. of variation of Cement.
				Tube 1.	Tube 2.	Tube 1.	Tube 2.	Tube 1.	Tube 2.	
Oct. 2	1	B } 5 S } C 1	6·25	1·20	1·30	2·40	2·50	0·50	0·52	4
Oct. 2	2	Ditto	6·25	1·30	1·20	2·20	1·90	0·59	0·63	7
Oct. 26	3	B 2 S 1 C ⅔	6·25	1·00	1·10	1·50	1·90	0·67	0·58	15
Oct. 26	4	Ditto	6·25	1·15	1·15	1·50	1·50	0·77	0·77	—
Oct. 28	5	B 4 S 2 C 1	4·21	1·10	1·00	1·30	0·95	0·85	1·05	24
Oct. 28	6	Ditto	4·21	0·97	1·05	0·90	1·12	1·08	0·94	15
Oct. 28	7	Ditto	4·21	0·95	1·20	1·05	1·55	0·90	0·77	17

of sand and cement should be used, to eliminate the error due to entanglement of cement in the sand.

The samples taken should be as small as is consistent with fairly accurate measurement.

They should be taken from parts in the heap of concrete as far removed from each other as possible, or where a difference in appearance is noticeable.

When the test gives a positive result it should be repeated before deciding that mixing is complete.

The test is very simple, and can be applied, with a little practice, by any engineer. Each test occupies about 15 minutes, and the apparatus costs only a few shillings. Hence it may be regarded as a works test, which can be used wherever concrete is being mixed.

DISCUSSION.

The **President,** in moving a vote of thanks to the author, said that the meeting had listened to an exceedingly interesting paper and one dealing with a very important subject. This might be called the concrete age. Concrete, as a material for construction, was increasing in importance every year, and therefore any test which enabled engineers to form an opinion as to the quality of the material which they were using must be of the greatest use. He had hoped that the author would tell them of a test which could be applied to concrete when it was actually in a structure, but he was afraid that such a test was unattainable. But the test brought forward in the paper was undoubtedly of very great value. The only weakness in the argument was the proposition that a mixing machine capable of turning out a certain quantity of concrete would not turn out a similar quantity of mortar, and that, consequently, if they found that the mortar was thoroughly mixed, they knew that the larger materials in the aggregate were evenly distributed throughout the mass. It seemed to him that there was a step missing in that argument. Even granting this limitation, however, the knowledge that the matrix was properly mixed was of very great value. The tests which had been carried out by the author seemed to have been conducted upon a highly scientific basis in order to eliminate, as far as possible, every error in the experiment. It was remarkable that the variation as between 2 to 1 and 3 to 1 in the proportion of sand and cement should not be visible to the naked eye. He had never tried the experiment in a definite way, but he should certainly have thought that it was possible to tell the difference between the mixtures. He had no doubt, however, that the author's experiments were correct. This showed how highly important it was that they should have other tests available.

Mr. W. Noble Twelvetrees said that he was much indebted for the invitation to be present at the meeting. In the first place, it gave him an opportunity of expressing his personal gratification that the Civil and Mechanical Engineers' Society, which he represented, would probably shortly be united with the Society of Engineers. A second reason for his indebtedness was that he had had the privilege of listening to a most useful and practical paper. Within recent years concrete had emerged from the stage of a rough and neglected material which many contractors, and more especially building contractors, had regarded as little better than earth filling, to be mixed anyhow and put anyhow into a hole where it could stand a certain amount of weight and serve as a foundation. During the last few years engineers and architects had become familiar with reinforced concrete, and were beginning to recognise what Dr. Owens had told them that evening, that, as in the case of a chain, the strength of concrete was governed by that of its weakest section, and therefore that it was necessary to be very careful in mixing the constituent materials, equal care being necessary with regard to the proportions of the ingredients. Proportioning could be done in the first place on paper, but the engineer had to depend largely upon the contractor for correct proportions and thorough mixing, and the contractor had to depend upon his men or his machine for satisfactory performance of the mixing process.

With regard to the test which Dr. Owens had described, it seemed very strange at first sight that the layer of cement did not shrink any more after the first ten or fifteen minutes. He supposed that it did really shrink, but so slowly that the shrinkage was hardly perceptible. That was a point which the author would perhaps explain.

He should also like to know what was the condition of the cement in the layer. Was it still floating or had it settled into a kind of soft paste ? If it formed a paste with the particles in contact or practically so, he could understand that they could scarcely shrink more closely.

The experiments described were very interesting, showing that the test was a reliable one for practical work, and might be safely applied for general guidance. The idea of washing out the mortar from the stone was particularly good. By adopting it the test could be conveniently applied and the results interpreted with very little trouble because the ratios indicated could readily be compared one with another. But he thought that it would be a convenience to intending users if regular test sets could be obtained. If properly graduated tubes of the correct diameter and length, together with a funnel as described by the author, were obtainable in a ready way, packed in a case with simple directions for use, engineers and contractors would be far more likely to commence using the test than if they had to hunt up the particulars from the Transactions of the Society and design their own test apparatus, with the risk of being obliged to waste time in conducting preliminary experiments.

The President had mentioned a rather important point, namely, the testing of concrete after it had been put into position. Probably he had seen what others had seen, concrete consisting in one part chiefly of cement and in another part chiefly of stone. It was quite likely that the concrete had been correctly proportioned and properly mixed, but that a little interval of time had elapsed after the mixing, with the result that the stone might be at the bottom and the cement at the top. That sort of thing happened in the construction of columns where a very liquid concrete was poured into the moulds. In that case the bottom part of a column might be chiefly stone, the middle part chiefly sand, and the top part very largely cement. Of course, no test whatever would guard against that kind of thing. The only possible remedy was for the resident engineer or the clerk of works to keep a very sharp eye on what was going on.

Mr. D. B. Butler wished to add his quota of compliments to Dr. Owens for his very interesting paper. All research work was useful, and they especially welcomed in their Transactions papers embodying research, because they greatly added to the value of the volumes for reference.

His first criticism of the paper related to its title. He quite appreciated Dr. Owens' endeavour to make it as concise as possible, but he thought that in this case the author had, for the sake of brevity, fallen short of a proper description. When he first saw the title of the paper he was led to understand that it related to some test for ascertaining the strength of concrete. If the author had added one word to the title and called the paper " A New Test for Concrete Mixing," that would have conveyed its purport much better than the present title.

Next he took exception to the word " new," a term which was scarcely so accurate as it might be. He (Mr. Butler) happened, some five or six years ago, to have to review for the Press a little work by Mr. Dibdin in which exactly the same test was advocated for determining the composition of mortar. Hence he thought that the word " new " was not strictly accurate.

The paper referred to the methods at present in vogue for testing concrete, one of which, described as sound in principle, consisted of making briquettes of the concrete and allowing them to set for a certain length of time before being tested for tensile strain. But that method would only apply to the matrix or mortar, and obviously could not be used with concrete, which frequently contained stones up to $1\frac{1}{2}$ ins. diameter ; the largest briquette used for testing purposes was only $2\frac{1}{4}$ ins. in sectional area, viz., 1½ ins. by 1½ ins., and if a large stone, even of ¾ in., happened to be in the area of fracture, the test would be nullified. A better plan would be to have 3 in., 6 in., and even 12 in. cubes and test them for crushing stress in the ordinary way.

He did not quite agree with Dr. Owens' definition of properly mixed concrete. He should prefer that properly mixed concrete should be defined as concrete in which each particle of stone and sand was covered with a layer of cement, or (to put the definition the other way round) one in which no particle of inert material, either stone or sand, was in actual contact, without a layer, however thin, of cementitious material between.

In reference to Table II., Dr. Owens referred to a possible error of observation—plus or minus—of 0.02 of an inch. He had then the trouble to work out what difference the maximum error would make with test No. 5 in Table IV. He might mention by the way that nearly all the readings were given to the first decimal place only, very few of them to the second place. If in No. 5 the maximum error of 0·02 was allowed, the depth of the sand layers might be 1·12 and 0·98 instead of 1·10 and 1·00 respectively, and of the cement layers 1·28 and 0·97 instead of 1·30 and 0·95, as given in the table. If so, the ratio of sand and cement layers would be 0·87 and 1·01 instead of 0·85 and 1·01, or a percentage of variation of the cement of only 16 instead of 24. This strongly suggested that there was a possibility of huge experimental error in the readings of the test. He should like to ask Dr. Owens whether he had in any way checked his experiments by chemical methods, *i.e.*, determining the proportion by actual chemical analysis.

With reference to the question raised by the President as to a means of testing the proportions of set concrete, he (Mr. Butler) might say that it was done almost every day, or at all events frequently, in his chemical laboratory ; the proportion of cement and sand in concrete could be easily and accurately ascertained by chemical analysis, given, of course, an analyst of sufficient experience of that special class of work.

So far as he could see, he thought that the method suggested by Dr. Owens would require very much more thorough investigation before it could be accepted as a recognised test. It could at best only be used as a rough test to ascertain whether the mixing of two samples of concrete from exactly the same materials was satisfactory, and it was of no use for determining proportions.

With regard to Dr. Owens' method of washing the cement from the large stones into the matrix, it seemed to him that the large stones must introduce a very considerable element of error because there would be more or less cement round the stones, and the larger the quantity present the more cement there would be round them and the more would wash off into the test tube with the sand, which would give a correspondingly erroneous result.

Mr. T. E. Bower regretted that the paper was altogether concerned with testing concrete. He had had in his mind a superstructure about 600 to 800 yards long, 30 ft. high, and 10 ft. wide at the top, crossing a valley from one side to the other. The outside was faced with brickwork in old English bond. The piers and segmental arches were filled in with concrete, and four or five years after the structure had been erected it was found to be leaning over. The central part was curved and directly facing the sun on the convex side, but the other side never saw the sun ; there was therefore cold on one side and heat on the other, which in the summer caused a forward movement of about ½ in., and in the winter the backward movement was nearly ¼ in. No fault could be found with the foundations, which on examination were found to be very satisfactory. It would be some long time before anything serious could happen, but the structure was now 12 to 14 ins. out of the vertical. Of course, concrete on or below the surface was not subject to the climatic variations of a superstructure. He thanked Dr. Owens for his paper, which was exceedingly interesting as far as it had gone, but he (Mr. Bower) thought that he might have learned something about how such a matter as he described should be dealt with.

Mr. H. Puplett said that all Engineers who were responsible for ferro-concrete work were under an obligation to Dr. Owens for his paper, for he had certainly devised a means of testing the concrete that they were using, and had shown that to ensure a uniform concrete it was necessary to mix it in a machine and not by hand. In that opinion he had the very weighty support of Mr. C. F. Marsh, who, in the first paper that was read before the Concrete Institute, said : " As a rule machine mixing gives a more even concrete than hand mixing if batch mixers are used." Mr. C. J. Potter, in a paper which he read before the Society of Chemical Industry, at Newcastle-on-Tyne, said : " There can be no doubt that mechanical concrete mixers are a great safeguard as compared with the old method of hand mixing." Dr. Owens had shown that the percentage of variation in hand-mixed concrete might be said to depend upon the number of men who were engaged in the mixing gang, but with a machine they had only to deal with the influence of one man, and he could be checked by an engine-counter. He knew of three kinds of batch mixers, any one of which would produce a uniform concrete mixed to any predetermined extent. Those mixers were the " Messent," the " Taylor Side Delivery " Mixer, and a new machine patented by Messrs. Barker & Hunter. The first two had been on the market for years, and were well known as machines for mixing concrete in large quantities. The last had been designed to deal with small batches of concrete as needed for ferro-concrete work. He only quoted these as types to show that there was no difficulty in getting a machine to which some counting apparatus could be attached. They had one common feature: they could not be emptied without a definite mechanical operation being first performed. They must either have a door or doors opened or the machine must be reversed. Therefore, they were certainly batch mixers that might be relied upon to produce a uniform concrete provided the proportions of the materials were maintained and a fixed number of revolutions was given to each batch.

The point which Dr. Owens had made as to the inefficiency of an inspection of the mass as a means of determining whether concrete had been properly mixed was very important.

The tests of hand mixing were instructive, and pointed to the necessity of getting rid of the human element. They could only do that by using a batch mixer which was rendered compulsorily intermittent by the introduction of some mechanical operation to effect the discharge of the mixed concrete. Any continuous mixer or any gravity mixer was useless as a safeguard. They could only produce a uniform concrete by using a batch mixer of approved design in conjunction with some mechanical checks for gauging the material and for securing a definite amount of mixing. Dr. Owens had shown that a machine could thoroughly mix concrete in 20 seconds. That was much quicker than they could lay it *in situ*. Sir John Jackson, in speaking of a contract in which a million and a quarter cubic yards of batch-mixed concrete were used, said: "We have usually found that these mixers can really turn out the stuff quicker than it can be taken away." To increase that speed was a work of supererogation. The chief point of all was that Dr. Owens had devised a practical works test that could be applied by an engineer quickly and at very little cost on the buildings whilst they were in progress, and for the sake of the good repute and in the interest of all concrete work, plain or reinforced, it was imperative that some such tests as these, made with sufficient frequency, should be insisted upon.

Mr. George J. Fenwick said that on several hundred occasions during the last ten years it had fallen to his lot as head chemist in one of the best known cement specialists' laboratories to investigate the structure of concrete samples by the tedious and laborious process of removing the stones by hand and cleaning the cementitious matrix from them, and he could endorse the author's contention that uniformity of mixing was not so prevalent as could be desired. He must say, however, that if they presumed that the author's analytical work was above suspicion, the result of its application would still be open to several grave objections.

First, the method of sampling which implied that the mortar must be of the same composition throughout, independently of the proportion of stones. They might take as an example Thames ballast 4 parts, sand 2 parts, cement 1 part. No two loads of ballast were identical. If there were 20 per cent. of sand through a $\frac{1}{12}$ in. sieve in one load and 40 per cent. in another, the mortars would show 25 per cent. variation on the proportion of sand to cement, and to adjust this they would require 6 parts of ballast from the first load as against 3 parts from the second, a result which would lead to greater inequality.

Secondly, the larger stones segregated in certain parts of one batch of concrete, and thus the small testing samples would vary. As an example, he had taken a sack of ballast, and tested four samples of about 6 to 8 cubic inches. The residue on a $\frac{1}{10}$ in. sieve had varied from 30 to 60 per cent., although the sample had been stirred up several times.

Thirdly, there was the objection on theoretical grounds to the idea concerning the weakest link. There were two similar but utterly distinct forces which united a concrete—the cohesion of the cement and sand matrix and the adhesion of this matrix to the stones. These forces were not equal and might be vastly different. In the case of Thames ballast the adhesion was usually very low, owing to the smooth glassy surface of the flint pebbles, whereas with granite chips, broken brick, coke breeze, and boiler clinkers, it was comparatively high. It was thus evident that the "weakest link" was usually this force of adhesion; and, as the author's test ignored the possibility of the small sample being comparatively rich in large stones, and hence largely dependent on adhesion, its application would be valueless, if not worse.

Turning to the analytical data, the author was not by any means on firm ground. In Experiment 1, Dr. Owens had given the results of certain tests. Had he weighed the cement instead of measuring it, and measured the heights accurately instead of in round numbers, he would have found that the length of the columns was not strictly proportional to the amount of cement, but that the lower layers were compressed by the upper. He had tried this experiment himself and found, for example, that 5 parts of dry cement only occupied 4.3 times the space of 1 part when settled.

In Table I. there was another discrepancy. If they took the ratio of sand to cement this should be as 1 : 2 : : 3 : 4, whereas the proportions were as 1 : 2.16 : : 2.70 : 3.92. Moreover, columns 5 and 6 showed variations of nearly 10 per cent. As the method gave such unreliable ratios with known samples, it was of no use with unknown.

The author had told them that the temperature should be constant, and that 10 to 15 minutes were required for settling after the water had cleared. If they referred to Table II. they would find that both varied considerably. This table was Experiment 1 over again. Turning back to page 33, they would see that 60 grains of cement at 61 degrees F. occupied 0.55 in., whereas 80 grains occupied 0.80 in., a difference of nearly 10 per cent.

As a test of the remarks on page 39 he had weighed out 2 parts of sand and 1 part of cement so as to get different bulks of sand-cement mortar, but the same composition. With 200 grains cement, 400 grains sand, the bulks were almost equal, whereas passing down the scale to 50 grains cement, 100 grains sand, the sand was of only 80 per cent. the volume of the cement. Hence the sifting out of the stones did not show the true richness of the mortar in cement.

In Table III. the variation in the worst batch was 11 per cent., whereas from batch to batch there was a variation of 40 per cent., which bore out his previous remarks with regard to variation in loads of ballast.

In Table IV. it appeared rather significant that the larger the sample the less the variation.

He would suggest to the author that if any more experiments were made the true analytical method should be followed; eliminating all factors of variation in comparative tests, and experimenting under exactly similar conditions.

Mr. J. F. Plaister said he would like to refer to two points. In the first instance the author referred to the test as a new one. Mr. Butler had already said that the test could scarcely be called "new," and he (Mr. Plaister) could say, as a manufacturer of cement, that the test had been a very common one with some manufacturers for many years past, generally in connection with samples of concrete which they received sometimes from users stating that the concrete would not set, when it was usual to apply a test of this kind, not only to ascertain whether the concrete had been properly mixed, but also to ascertain the nature of the component parts of the aggregate. Then, again, Dr. Owens said that this was a practical test which could be carried out in a few minutes. He (Mr. Plaister) had made a great number of experiments, quite apart from the tests referred to, in connection with hollow concrete blocks (and he did not think that anything would give one a greater insight into the necessity of mixing the concrete thoroughly and properly than the manufacture of those blocks). In making these experiments he had followed much on the lines of Dr. Owens, and he soon found that the quickness of the test depended entirely on the nature of the aggregate and the nature of the cement which was being used. Some cements would take many hours to give a really reliable result, whereas with others the test would be carried out in a comparatively few minutes. For instance, the cement which was floating in the water entirely depended on the nature of the cement and the quantity of flour in it. If a cement contained a quantity of fine heavy grit, as many of the cements of the present day did, it would settle very quickly, and it would be difficult, except by analysis, to separate some portion from the sand. Again, a really good cement containing plenty of flour would take a long time to settle, and occupy far beyond the 16 minutes ; in fact, it would sometimes take a couple of hours. The same might be said of some of the aggregates. Dr. Owens appeared to have carried out his experiments with some rather heavy aggregates. He should have taken some ot the lighter aggregates as well, when he probably would have found his tests take a much longer time.

Mr. Henry C. Adams said that Dr. Owens had carried out some very exhaustive experiments, and had made careful analyses, but he should like to know what sand was used in making the experiments. He (Mr. Adams) had made some experiments in a very similar way some years ago for the purpose of a rough comparative test of samples of sand. On a sample being shaken up in water all the loam would float out and remain on top, while the heavier sand would settle at the bottom. Unless the sand used by Dr. Owens had been washed absolutely clean, the loamy matter would be mixed with the cement, and would affect the accuracy of the test. The mixing of concrete was of quite equal importance to the quality of the material, but he did not think that Dr. Owens had given hand mixing quite a fair chance. The concrete referred to in the paper had been turned over twice dry and twice wet, but he (Mr. Adams) did not think that that was enough, and he always had it turned five or six times. It was difficult to keep the mixing up to any particular standard, and the mixture was often specified stronger than was necessary in order to allow for contingencies. In hand-mixed concrete waste might occur through wind blowing away some of the cement, but in machine-mixed concrete waste was eliminated. There was another disturbing factor brought in when the concrete was sent down a shoot as it became separated before it got to the bottom, so that they obtained unequal deposition, although the first mixing might have been well done. He thought that in concrete mixing a very much better result was obtained by making the mortar first and adding the stones afterwards.

He did not quite follow why it should not be possible if the test was an accurate one to make a standard. The materials that were being used could be combined into a standard mixture of 4 to 1 or 5 to 1, and then casual samples could be taken during the day and compared with the standard mixture. Of course, different consignments of cement or ballast would give different results, and, therefore, the standard mixture would have to be made somewhat frequently. But it seemed to him that Dr.

Owens limited his test to proving that the mixing was even. It did not matter whether it was comparatively stronger than somewhere else. All that they wanted to know was whether the sample which they took was of sufficient strength.

Professor R. H. Smith said that reference had been made to the formula for the velocity of descent of particles in water, but Dr. Owens' method did not depend in the least on that or any other formula, but simply upon the fact that the sand fell a great deal more quickly than the cement.

The author spoke of what he called the curious phenomenon of the thickness of cement observed in the test tube increasing with the repeated subsequent mixing up. He should like to ask whether that was due to a partial chemical combination taking place during the repeated mixing up.

He should also like to know whether the method of separating the constituents while still dry by air currents had ever been used. If they formed a narrow box with two parallel walls, and if one of the narrow sides of the vessel was perforated with a large number of small holes and air was blown through the perforations so as to produce a large number of horizontal jets of air, and the mixture was caused to fall through these jets, the air would blow the cement further than it would blow the sand, and it would hardly blow the gravel at all. The three constituents could thus be collected in separate receptacles. That method of separation of the constituents of a solid mixture had been employed in other kinds of experiments and also in many industrial processes, and it was very effective. It had been applied only with dry mixtures, but it seemed at least possible to apply it to wet mixtures with horizontal jets of water substituted for the air jets.

Mr. C. F. Gettings asked the author with regard to separating the stones and washing the cement and sand, whether he had the stones specially gauged. It appeared that unless they were of an absolutely uniform size he did not see how they could arrive at a definite quantity, assuming that the samples were taken from a heap in five or six different positions.

Mr. J. Weston referred to the author's statement that the lines of demarcation between the stones and sand and cement were perfectly distinct, and said that, supposing there was dirt in the sand (which would lie between the cement and the sand) it would be rather difficult to measure the thicknesses correctly, and might produce a large error.

With regard to hand mixing, he endorsed the view of one of the speakers who said that the author had been too severe in his condemnation of this method. He should like to ask Dr. Owens' opinion as to how many turns should be given to hand-mixed concrete to produce an uniform mixture if the process was carefully carried out.

The **President** submitted the vote of thanks to the meeting, and it was carried with acclamation.

Mr. C. H. Colson wrote, saying that the test suggested by Dr. Owens was an ingenious one and likely to be of considerable use in determining the number of revolutions that should be given to any specified material in any "batch" machine, the speed of output that should be allowed to a continuous concrete-mixing machine, or the number of turns that should be given to hand-mixed concrete ; but he did not think that it could be used as a test while concrete mixing was in progress, as it would be practically impossible to suspend the deposition of the concrete after mixing for even ten minutes while the test was being made.

Apart from the difficulties with a contractor to which such a proposal would certainly give rise, it was possible that the delay might have a very damaging effect on the concrete, especially when quick-setting cement was being used.

The test on October 26th, given in Table IV., showed that it was possible, by turning twice dry and twice wet, to produce a uniform mixture, but the considerable variation from uniformity shown in some of the other experiments given in the same table suggested that it would always be advisable, where it is necessary to mix the concrete by hand, that the number of turns should be increased, and if Dr. Owens would make further experiments to determine what number of turns should be specified with various materials to ensure a uniform mixture, the information gained would be of great value to the profession.

Dr. Owens, replying to the discussion, alluded to the President's remark that he had hoped to hear of a test for concrete in position. With all due respect to the President, he would say that what they wanted was to make sure that proper concrete was put into position. It was advisable to find out whether a mistake had been made, but it was better to prevent the mistake. The President disagreed with his theory that the mixing of mortar was more difficult than the mixing of coarse particles. He (Dr. Owens) thought that he could prove satisfactorily that it certainly was so. It was common knowledge that a man required to mix mortar very much longer to get a fairly decent mixture than he would to mix concrete with coarse particles ; and in a mixing machine it required longer to mix mortar of fine sand and cement than coarse gravel and cement. From a theoretical point of view it was obvious that it should be easier to mix coarse than fine materials, because the mixing was really a question of bringing the particles of the different ingredients together. In fine materials there were more particles to be moved. Obviously, the greater the number the longer the process.

With reference to the utility of inspection as a test for concrete mixing, he had put in many thousand yards of concrete, and he could never see, even from close observation, that when concrete was fairly well mixed, though probably not quite uniform, it was improved in appearance by further mixing. The test of the value of inspection referred to in the paper was made with the special object of finding out what the limits of inspection were. He did not rely upon his own observation only, but he had another observer, an artist, to come and look at the colour, and no difference could be detected until the variation in strength of the samples compared was considerable. He would not insist on the impossibility of distinguishing between 2 to 1 and 3 to 1, but certain it was that they could not detect any difference in appearance between 2 to 1 and 2½ to 1, which is quite enough to prove the uselessness of inspection alone. The usual stipulation that concrete should be mixed until it was of uniform colour was, therefore, in his opinion, quite useless as a test of thorough mixing.

Mr. Twelvetrees had asked about the curious point of the settling of the cement to a minimum thickness in ten minutes. Such cessation of contraction in the cement layer happened in every case, but he (Dr. Owens) did not pretend to explain the reason. After about that time the shrinkage appeared to have ceased entirely, observations twelve hours later showing no further contraction.

As to the condition of the layer, it was in the form of paste. He could not say whether the particles were touching, but he thought not ; it appeared that, up to a certain point, the water was gradually displaced by the particles passing through it, and after a certain time they arrived as nearly in contact as it was possible for them to do. Possibly there was a layer of water always separating the particles, which their weight was insufficient to displace. This was supported by the fact that the volume of the cement layer, when at a minimum thickness, was always greater than that of the dry cement.

Mr. Butler's remarks *re* the title were apropos, but this was a test for concrete, and he (Dr. Owens) did not wish to make it too narrow. He had not seen Mr. Dibdin's account of a similar test, and, so far as he (Dr. Owens) was concerned, this test was new. Of course, he was aware that the method of mechanical analysis had been in use for years, but what he believed to be new was the application of the test by sedimentation to determining whether concrete was mixed or not.

He did not think that the criticism which had been made about briquettes really held good. There was a slight misunderstanding. He did not use the term " briquettes " as necessarily meaning the small test blocks for breaking by tension, but rather something like a beam or slab, a thing which could be broken upon a couple of supports. They did not specially want tensile strength. All they wanted was to know whether the briquettes made from the same batch of concrete were of the same strength, whether transverse, tensile, or crushing. So long as they were of the same strength, though from different parts of the heap of concrete, the mixing would be complete.

He did not agree with Mr. Butler's definition as to the mixing of concrete, although he was aware that it was the accepted definition. Everybody would say that concrete was mixed when the particles were thoroughly covered with cement ; but he did not agree with that view because it was quite possible to have all the particles coated and yet have far more cement at one point than at another. The coating might be thick on some, thin on others, and still they would all look alike. The covering of the particles occurred, in point of time, before the mixing was uniform, and that was why he abandoned Mr. Butler's definition. In the hand-mixed concrete that he tested all the particles were covered with cement and water as far as he could tell by inspection. And, after all, what was the definition of a mixture ? A mixture was not complete until all the particles had been mixed as uniformly as their sizes would permit. The sizes of the particles introduced a difficulty. It was impossible to get absolute uniformity. Mr. Butler asked him whether he had checked the test by chemical analysis. He had not, but he made small samples containing known quantities of cement, and he put the whole of the samples to the test. This method admitted of no mistake, and some of the tests that were described in the paper were done in that way, so that if the test was sound it should indicate the amount that was put in, as it did. The test was not intended for a laboratory test, and he was not working by methods which could not be applied on the works, because such would not be useful to the engineer.

Referring to the percentage variation of the cement in hand-mixed concrete, it was not of great importance what the exact percentage was ; the really important point was that there was a considerable variation in the proportion of cement in different parts of the concrete due to imperfect mixing. The error of 0·02 in. referred to on page 38 had reference only to Table II.

As to the washing of the cement off the stones, he did not think that he had made himself quite clear. The end of the mixing was indicated by an equality in the amounts or in the ratio of the sand and the cement in each sample. If the mixture was complete there ought to be the same quantity of stones and small particles of gravel in each sample, as the samples were the same size, and therefore there should be the same amount of cement washed off each. If there was not the same amount it was because the mixture was not complete. It did not, therefore, invalidate the test in any way to have gravel in the sample.

Whatever the concrete was made of, all the things were mixed up together, and the sample should be representative if the mixture was complete.

Mr. Puplett's remarks about mixing he agreed with. He (Dr. Owens) had no doubt that machine mixing was superior to hand mixing. The foreman of the works where he made some of the tests expressed the opinion that there was nothing like hand mixing ; and the particular sample in which he got the 24 per cent. variation in the cement was hand mixed under that foreman. It was hand mixed by the mixing gang without any special supervision, and that was the chief drawback to hand mixing—the uncertainty of it. He would not say that it was not possible to mix by hand properly. It depended, to a great extent, upon the personal factor, but it was supposed to depend on the number of turns that the concrete got ; it did not depend upon the number of turns, for one man would turn it in such a way that it would be mixed, and another man would turn it in such a way that it would not be mixed.

The criticisms made by Mr. Fenwick were based upon misunderstandings or misstatements. Mr. Fenwick said that the proportion of sand in Thames ballast varied very much, but that had nothing whatever to do with the validity of the test, and had no bearing upon it ; for he never attempted to compare one batch of hand-made or machine-made concrete with another. He was attempting to test the mixing of a batch, or one mixing, that had in it a certain amount of Thames ballast. Whether it had 4 parts gravel to 1 of sand or 6 parts to 1, the proportion made no difference to the test, and had not the slightest bearing on it. It was true that the Thames ballast contained a very variable quantity of sand, but when mixture was complete surely the sand should be distributed uniformly. One batch had nothing to do with the other. The tests in Tables III. and IV. were each made with different batches, and therefore no attempt should be made to compare the sand and cement in one test with that in another if of a different batch, as a variation in the proportion of sand makes such comparison useless when regarded as a test of mixing. He was testing the mixing and not the proportion. He was testing each individual batch on its own merits. If it had 4 parts sand to 1 cement it would come out with certain definite layers of sand in the two test glasses, and if it had 10 parts to 1 it would come out with thicker layers, but the layers in the two glasses in each case would be equal. Something was said by Mr. Fenwick with regard to the thickness of the layer of cement. There, again, there was a misunderstanding. It was only when the samples contained the same or nearly the same thickness that uniformity of mixture was indicated. If the samples contained the same amount of cement, surely it made no difference what the amount was, or whether a thick layer was more compressed than a thin one. When the two layers of cement and the two layers of sand in each sample became equal the mixture was uniform, because all possible errors due to compression and other causes were eliminated by the equality.

Mr. Fenwick did not agree with him that the test could be made in 10 or 15 minutes. He did not say that that was the time one would expect to be necessary, or that it was the right length of time to carry out the test, but he did say that in scores of the tests which he had performed it was the actual time required. It simply took 10 or 15 minutes, as a matter of actual observation, for the cement to settle through about 18 ins. of water, but the time depended greatly on the amount of cement present, as shown in the paper. In Table III. he was not attempting to compare the batches ; but the mixing of each individual batch, a point which had clearly not been grasped by Mr. Fenwick ; each of the five tests in the table was of a different batch.

It had been said by Mr. Plaister that the test was not new and that he had used it, and Mr. Butler had said the same. He (Dr. Owens) thought that there was a misunderstanding on this point. He was using the method of sedimentation, which had been used from time immemorial for analysing soils and that sort of thing, but he was using it in a new way as a new test and for a new purpose. Mr. Plaister made a criticism as to the time required for the cement to settle depending on the amount of flour contained ; the flour should be very much longer than the rest in settling, and he took it that Mr. Plaister's argument was that the more the flour the slower it would settle. That was quite true, but with the very finest cement it settled in a very short time, such as 10 or 15 minutes, according to the depth of the water. The settlement of any particle depended only on two things—the specific gravity and the size—and upon nothing else, assuming that the particles were placed in the same water with the same temperature and under similar conditions. Consequently, the smaller part of the aggregate settled more slowly. The gravel dropped to the bottom first, the sand came down afterwards, and the finer parts on the top.

Mr. Adams referred to another supposed fallacy due to loam in the sand. He (Dr. Owens) had the same answer to that as before. What Mr. Adams referred to made no difference whatever to the test, because if the mixture was complete the same amount of loam would be present in each sample, the loam would be mixed with the other ingredients, and it would not affect the result. It would simply introduce another ingredient which would come down with the cement. He had made the test with both clean washed sand and sand containing enough loam to muddy the water, and found it worked perfectly. He agreed with Mr. Adams that hand-mixed concrete turned twice dry and twice wet was not sufficiently mixed, but he did not fix the number of turns which the mixture was to get. He simply went to a work that was being done by a first-class contractor, and tested the concrete which was being used. Of course, it got further mixed after it left the banker by shovelling into the barrows, etc. He thought that the contractor knew what was being done, and calculated upon this further mixing.

Professor Smith remarked that the gravel that was used with the sand would invalidate the comparison of the amount of sand in each sample. But he (Dr. Owens) did not use the gravel with the sample. He washed it out, and this brought him into opposition with Mr. Butler. In some experiments that he had made he found that leaving the gravel in worked all right, except that if there did not happen to be a little more sand than was sufficient to fill the voids in the gravel, it ran down between the particles of gravel, and did not leave an even surface. If they had enough sand to fill the voids in the gravel they could make the test all right, except that it was more convenient to remove the gravel ; if they took the same sized sample from each part, the thickness of the layer of cement was all that they had to think about, and the sand might be neglected. He did not quite agree with Professor Smith on this point. The Professor said that the formula giving the rate of settlement of the different particles had nothing to do with the test. He (Dr. Owens) thought that it had, and he had tried to point out the reason in his paper. It was a rather curious point. In fact, the cement did not appear to obey the same law at all as the sand. The rate of settlement of the particles through the water depended upon size and specific gravity. But when that was said it was not everything, because when the particle became very small it seemed to break away from the law which governed the larger particles and obey a different law, not well understood ; and the cement, being very much smaller, happened to be below that critical point, so that it settled very much more slowly than the sand.

Professor R. H. Smith desired to correct a misunderstanding. He had not said that it did not depend upon the difference of velocities of settlement, but that this particular law which was stated in the paper had really nothing to do with the test, because the test wholly depended upon the very great difference between the two velocities at which the two materials sank, and it did not matter whether the one velocity was governed by a certain mathematical law or not, so long as this very great difference existed between the two.

Dr. Owens agreed ; but what he wanted to bring out was that there was a very great difference in their rate of descent.

As to the air jets, they would not apply to the testing of wet materials. Mr. Gettings had remarked on the separation of the stone from the sand. He (Dr. Owens) did not see that the gauging of the stone had anything to do with it. If the mixture was complete the samples should contain the same representative particles of stone. He could not answer Mr. Weston's question as to how many turns hand mixture should require. It would depend upon the man who did the work.

Dr. Owens also wrote, saying that in view of Mr. Butler's remarks as to the novelty of the test, he had, since the meeting, looked up Mr. Dibdin's test as described in his book ; but could not find that it anticipated his own as a test of mixing concrete. It was simply an application of sedimentation as a rough test of the composition of lime mortar, and no suggestion was made as to using the method as a test of uniform mixing for concrete.

April 5th, 1909.

EDWARD JOHN SILCOCK, PRESIDENT,
IN THE CHAIR.

THE CORROSION OF STEEL REINFORCEMENT IN CONCRETE.

BY ERNEST R. MATTHEWS, A.M.INST.C.E., F.R.S.E.
[MEMBER.]

It has been said that reinforced concrete should be avoided as it is a treacherous material to use owing to the fact that the metal corrodes, and being covered by the concrete the extent of the corrosion can never be ascertained, and therefore many well-known Engineers up to the present have avoided the use of the material owing to this impression. If they were right in their assumption, and the steel did corrode, and there was no remedy for it, then reinforced concrete would soon have had its day, for its weakness in this respect would become generally known, and it would naturally be avoided, but, from a series of experiments which the author has recently made, and which he describes in this Paper, he is in a position to state definitely that no such fears need be entertained. Before describing his own experiments, he would in a few words set forth the gist of the information which we already have in relation to this important matter. In America the subject has received a good deal of consideration, and the commonly accepted theory in the United States respecting corrosion of iron in concrete is that stated by Prof. S. B. Newbury, which is as follows :—

" The rusting of iron consists in oxidation of the metal to the condition of hydrated oxide. It does not take place at ordinary temperatures in dry air, or in moist air free from carbon dioxide. The combined action of moisture and carbonic acid is necessary. Ferrous carbonate is first formed ; this is at once oxidized to ferric oxide and the liberated carbon dioxide acts on a fresh portion of metal. Once started the corrosion proceeds rapidly, perhaps on account of galvanic action between the oxide and the metal. Water holding carbonic acid in solution, if free from oxygen, soon acts as an acid and rapidly attacks iron. In lime-water or soda solution the metal remains bright. The action of cement in preventing rust is now apparent.

Portland cement contains about 63 per cent. lime. By the action of water it is converted into a crystalline mass of hydrated calcium silicate and calcium hydrate. In hardening it rapidly absorbs carbonic acid and becomes coated on the surface with a film of carbonate, cement mortar thus acting as an efficient protector of iron and preventing the carbonic acid molecules from attacking the metal. The action is therefore not due to the exclusion of the air, and even though the concrete be porous, and not in contact with the metal at all points, it will still filter out and neutralize the acid, and prevent its corrosive effect."*

Some very important tests have been carried out by Prof. C. L. Norton, of the Massachusetts Institute of Technology, Boston. These were conducted on the following lines. The blocks were made of :—

(*a*) Neat Portland cement.
(*b*) 1 part cement and 3 parts sand.
(*c*) 1 part cement and 5 parts broken stone.
(*d*) 1 part cement and 7 parts well washed cinders.

The reinforcement of each block consisted of a $\frac{1}{4}$in. rod, a piece of soft steel, 6 in. × 1 in. × $\frac{1}{16}$ in., and a 6 in. × 1 in. piece of expanded metal. The tests were as follows :—

One-fourth of the blocks were allowed to remain in air inside a building.

One-fourth were placed in a sealed box in an atmosphere of air and steam.

One-fourth in a sealed box in an atmosphere of air and carbon dioxide.

One-fourth in a sealed box containing an atmosphere of steam, air, and carbon dioxide.

Some of the reinforcement was dipped in cement grout previous to insertion in the concrete, but in other cases it was not.

The results of these experiments led Prof. Norton to the following conclusions :—

" (1) That neat Portland cement, even in thin layers, is an effective preventative of rusting.

(2) Concrete, to be effective in preventing rusting, must be dense and without voids and cracks. It should be mixed quite wet, when applied to the metal.

(3) The corrosion found in cinder concrete is mainly due to the iron oxide, or rust, in the cinders and not to the sulphur.

(4) Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel.

(5) It is of the utmost importance that the steel be clean when bedded in concrete. Scraping, pickling, a sand-blast, and

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* *Vide* "Reinforced Concrete," by Buel and Hill.

lime should be used, if necessary, to have the metal clean when built into the wall."

These tests extended over a period only of three weeks, which, in the author's opinion, was not long enough.

For years past French engineers have protected many of their iron bridges by coating them with cement wash, two coats being usually applied, and in America cement wash has been largely used for a similar purpose.

M. Breuille, of France, states that from his experiments he came to the conclusion that in all cases the action of the cement in the concrete on the iron reinforcement prevented rust, and that it even removed the rust from iron which was already rusty when embedded in the concrete.

The question of the rusting of steel in concrete has received the attention of German engineers, and numerous tests have been made, the general conclusion arrived at being that cracks occurring in the concrete do not result in the reinforcement becoming corroded at these points. The method of testing was briefly as follows :—

Beams were prepared which were reinforced by the steel which is generally used in reinforced concrete structures, this steel being placed 1¼ inches above the bottom of the beams. The concrete was mixed in the following proportions :—1 : 2 : 4, 10.1 per cent. of water being added. The forms were removed after a set of 24 hours ; the beams were then stored for three months, some in wet sand, others in the open air, water being poured over them daily. For the next three months the beams were subjected to load tests, and of 58 beams made 26 were broken under these tests. The 32 beams which had not been broken were then subjected to a rusting test under a load, sheet iron casing being fixed around the middle third of the beam, through which a mixture of carbon dioxide, oxygen and water vapour passed. The beams were kept in this rusting atmosphere for three days from 7 a.m. to 4 p.m. The steel was then examined with the following result :—

In 27 out of the 32 cases no rusting had occurred. These 27 beams had been subjected to a load causing stresses of 18,000 lb. to 35,000 lb. per square inch in the steel, and the five remaining beams had been subjected to a greater stress, viz. :—35,000 lb. to 44,000 lb. per square inch.

Mr. J. M. Braxton, Assistant Engineer at Key West, Florida, U.S.A., recently reported to the Engineer Officer in charge of the fortification works on the East Coast of Florida that he had made 15 sets of two blocks each, the aggregate in five of these sets consisting of three parts of coral sand, common to the beaches of the Florida Coast, and five parts of bricks crushed to pass through a 1-inch ring ; in five others it consisted of three parts of coral sand to five parts of brick crushed to pass through a 2-inch ring, and in the remaining five blocks it consisted of three parts of silica sand and five parts of brick crushed to pass through a 1-inch ring. The blocks were 12 in. × 12 in. ×6 in. The reinforcement, which in each case was inserted in the middle of the blocks, consisted of twisted steel rods 8 inches long and $\frac{5}{8}$ inch diameter.

Some of the rods were dipped in grout, and others were not treated in any way.

Half of these blocks were placed in the ocean after a 24 hours set, and half were exposed to the air.

At the expiration of a period of 1 year and 21 days these blocks were broken and it is interesting to note that the rods in those blocks which had remained in the sea water showed no signs of rusting, but those which had remained in air showed very slight rusting, regardless of the aggregate of which the blocks were made.

Some interesting tests were carried out a short time ago at the National Physical Laboratory, London, at the request of Sir John Brunner, and the following is the official report of these experiments :—

"A strong wooden box was made and divided into five partitions, each partition being 12 in. long., 7½ in. wide, and 7½ in. deep. Specimens of mild steel of the following dimensions were prepared : (1) One inch diameter, 8 in. long, turned all over. (2) Eight-inch lengths cut from 1½ in. by 1½ in. bar with the scale left on. The partitions were half filled with good Portland cement concrete, and a specimen of each kind of steel laid on the top, the partitions being then completely filled with concrete. This was done on December 21st, 1906. The blocks were covered with water several times per week for a year, and for three months afterwards they were left in the open, exposed to the weather. On April 20th one of the blocks was removed from the box and broken up, and the specimens removed. On examining the specimens carefully no trace of any action by the cement could be detected. The turned specimen was practically as bright as when it was put in, and the scale on the rough specimen was undisturbed. To test the possibility of any slight action, the surface of the turned specimen was polished and etched and examined under the microscope side by side with a specimen of the same material cut from the centre of the bar. No difference in the microstructure of the two specimens could be detected, and the conclusion is that in 16 months no action has taken place between the metal and the concrete."*

While the preceding information is undoubtedly valuable it will be readily seen that the results of the investigations vary considerably.

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* *Vide* "Concrete and Constructional Engineering," Vol. III., No. 3.

Prof. C. L. Norton found that corrosion took place when cinders were used as the aggregate of the blocks made by him; he also informs us that to dip the metal in cement grout was a sure proof against corrosion, but the metal must be clean before being dipped. This opinion is practically the same as that expressed by Prof. S. B. Newbury.

M. Breuille, of France, found that no corrosion took place when steel was inserted in concrete, but that the reverse occurred. He put rusty bars into concrete blocks, and when these blocks were broken some time after, they were found to be quite bright.

Mr. J. M. Braxton, on the other hand, found that slight rusting occurred when the blocks were placed in air, and that when submerged in sea water no corrosion of the metal occurred, while Sir John Brunner's tests indicate that no corrosion takes place when the blocks are placed in water and air alternately. In the German tests no corrosion occurred when reinforced beams were placed in air and others in wet sand, and afterwards subjected to a test load applied to produce a stress in the steel which did not exceed its elastic limit. The report of the special Committee appointed by the Royal Institute of British Architects respecting this important matter should here be quoted. Their report, after dealing with other characteristics of reinforced concrete, goes on to say :—

" It is sometimes thought that the metal may perish, but all experience shows that concrete is the best preservative for iron or steel known to us. A bar of iron or steel, slightly rusty, embedded in properly made concrete, may be taken out after some months, or after hundreds of years, brighter than when it was put in. Perhaps I may quote (says Mr. W. J. Locke, the late Secretary of the R.I.B.A.) the experience of Mr. Somers Clarke, late Surveyor to St. Paul's Cathedral, who being anxious as to the condition of the great chain tie which binds the dome at its base, caused an opening to be made in the concrete in which it has been embedded for over two hundred years, and found the iron bright and perfect, notwithstanding the fears which had naturally been felt because of the percolation of water from the gallery over it. This is but one of many examples, showing not only that metal reinforcements and concrete have been used by architects for many years back, but that their confidence in the durability of concrete and metal in combination is justified.

The many instances of the anchor chains of suspension bridges being embedded in concrete as a provision against their deterioration through the action of moisture may also be cited as showing the reliance placed on concrete by engineers for the protection of steel from corrosion."

The author, about 2½ years ago, had occasion to pull down part of a concrete sea wall at Bridlington which had been built 25 years previously, and he found that the iron chains which had been inserted in this wall at the time of its construction were still in a perfect condition; there being no sign of rust in spite of the fact that the sea covered the lower portion of the wall at every tide, and that in some places the chains were within an inch of the outside face of the wall.

The author will now describe the experiments recently made by him.

He set himself the task of discovering something definite on 14 points, which are as follows :—

(1) The effect upon the steel reinforcement of submerging blocks in 3 feet of fresh water, 7 days after making them, and keeping the blocks in water for 11 weeks. (Steel untreated.)

(2) The effect upon the steel of submerging blocks in 3 feet of fresh water after a 48 hours' set, and keeping the blocks in water for 11 weeks and 5 days. (Steel untreated.)

(3) The effect upon the steel when the blocks are kept exposed to the air for 12 weeks. (Steel untreated.)

(4) As No. 1, but when the steel is first dipped in cement grout.
(5) As No. 2, ,, ,, ,, ,, cement grout.
(6) As No. 1, ,, ,, ,, ,, linseed oil.
(7) As No. 2, ,, ,, , ,, linseed oil.
(8) As No. 1, ,, ,, ,, ,, turps.
(9) As No. 2, ,, ,, ,, ,, turps.

(10) The effect upon the steel of keeping blocks, after a 7 days' set, in water and air for alternate weeks for 11 weeks. (Steel untreated.)

(11) The effect upon the steel of keeping blocks in water and air for alternate weeks for 11 weeks and 5 days after a 48 hours' set.

(12) The effect upon rusty steel when the blocks are submerged in water for 11 weeks after a 7 days' set.

(13) The effect upon rusty steel when the block is submerged in water for 11 weeks and 5 days after a 48 hours' set.

(14) As No. 13, but exposed to the air for 12 weeks.

The author had 20 concrete blocks made, formed of various aggregates, each being 8 inches cube. In some instances the aggregate consisted of :—4 parts broken bricks, 2 parts sand, 1 part Portland cement. In other instances the proportions were :—3 parts ¾ in. gauge slag, 1 part ⅛ in. and dust slag, 1 part sand, 1 part Portland cement; also :—2 parts ¾ in. gauge slag, 1 part ⅛ in. and dust slag, 1 part coke breeze, 1 part Portland cement; also :—2 parts broken stone, 2 parts ¾ in. slag, 1 part sand, 1 part Portland cement; also:—3 parts slag, 2 parts sand, 1 part Portland cement.

The analysis of the cement used was as given below:—

CHEMICAL ANALYSIS.

	Per cent.
Insoluble residue	0.82
Silica	20.43
Alumina	9.10
Oxide of iron	1.95
Lime	62.65
Magnesia	1.25
Sulphuric anhydride	1.38
Loss on ignition	1.66
Alkalies and loss	0.76
	100.00

The metal inserted also varied; in some cases it was put in in a rusty condition, in other cases it was clean. Some pieces of steel were dipped in cement grout, others in linseed oil, and others in turps.

The date when each block was made, the aggregate of which it was composed, the condition of the steel reinforcement when inserted, and the tests to which it was subjected, are clearly set out in the following table (see pp. 8 and 9).

Block No. 1.—One piece of steel which was inserted in this block was rusty, it consisted of a short $\frac{3}{4}$ in. round bar. The block, after a 48 hours' set, remained in water until broken on October 13th (11 weeks and 5 days). The author was surprised to find that this bar had improved considerably in appearance, and that where it was not actually pitted with oxidation, it had become quite bright, which was certainly not the case when placed within the block; he also found that the pitting had been considerably arrested.

The bright piece of steel which was inserted in this block was in precisely the same condition when taken out on October 13th.

Block No. 2.—Two pieces of very badly corroded metal were inserted in this block; these consisted of $\frac{3}{4}$ in. and $\frac{5}{8}$ in. round steel bars, and the block remained in air for 12 weeks. The author found that the steel had considerably improved, so much so that it was scarcely recognizable, most of the rust having disappeared.

Block No. 3.—This block was placed by the author upon the foreshore at Bridlington, but was so covered by the sand that it has not been found.

TEST BLOCKS IN REINFORCED CONCRETE.

Date when block was made.	No. of Block.	Aggregate.	Steel.	Test to which the blocks were subjected.
1908 July 20	1	4 parts broken brick ... 2 ,, sand ... ... 1 ,, cement	1 piece rusty ... ... ,, clean	Placed in water after 48 hours.
,,	2	Ditto	2 pieces rusty	Remained in the open air.
,,	3	Ditto	3 ,, rusty	Placed in sea water 9 days after being made. Taken out of moulds 48 hours after making. This block was lost, so must not be included in these tests.
,,	4	3 parts $\frac{3}{4}$ in. gauge slag ... 1 ,, $\frac{1}{8}$ in. and dust slag 1 ,, sand ... ... 1 ,, cement	3 pieces clean steel	Kept in water after a 7 days' set.
,,	5	Ditto	Ditto	Remained in the open air.
,,	6	Ditto	3 pieces dipped in linseed oil ...	Kept in water after a 7 days' set.
,,	7	Ditto	3 ,, ,, in turps ...	Ditto
,,	8	Ditto	3 ,, clean	Placed in sea water 9 days after being made. Taken out of moulds 48 hours after making.

,,	9	Ditto	3 ,, ,, … …	Placed in water 48 hours after making.
July 22	10	2 parts $\frac{3}{4}$ in. gauge slag … 1 ,, $\frac{1}{8}$ in. and dust slag 1 ,, coke breeze … 1 ,, cement … …	2 pieces dipped in linseed oil …	Remained in the open air.
,,	11	Ditto	2 pieces dipped in turps …	Ditto
,,	12	Ditto	2 ,, clean … … …	In air and water for alternate weeks.
,,	13	Ditto	2 ,, dipped in cement grout	Kept in water after a 7 days' set.
,,	14	Ditto	2 ,, rusty … … …	Ditto
,,	15	Ditto	3 ,, rusty … … …	Ditto
,,	16	2 parts broken stone … 2 ,, $\frac{3}{4}$ in. slag … … 1 ,, sand … … 1 ,, cement … …	2 pieces clean … … …	Remained in the open air.
,,	17	Ditto	2 ,, ,, … …	Ditto
,,	18	Ditto	3 ,, rusty … … …	Ditto
,,	19	3 parts slag, 2 sand and 1 cement	2 pieces clean steel dipped in cement grout	In air and water for alternate weeks.
,,	20	Ditto	Ditto	Kept in water after a 7 days' set.

Block No. 4.—Three pieces of clean steel were inserted in this block, the latter being kept in water after a 7 days' set, for 11 weeks. No rusting whatever occurred in these pieces of steel, notwithstanding the fact that the concrete was not particularly dense.

Block No. 5.—Three pieces of practically new steel (same as in No. 4 block) were here inserted, and the block remained in air for 12 weeks. The marks of corrosion which appear on the end of the round bar were there when the bar was inserted. The rusting, however, has considerably diminished, and it will be noticed upon close inspection of the bar that it is disappearing.

Block No. 6.—In this block three pieces of fairly clean steel, which had been previously dipped in linseed oil, were inserted. The block was placed in water 7 days after making, and broken after it had remained in water for 11 weeks.

The author does not consider that this method of treating steel is a success, the coating of cement from the concrete being in his opinion a better preservative than oil. The slight marks of corrosion which occur on these bars were there when the steel was inserted.

Block No. 7.—Three pieces of clean steel previously dipped in turps were inserted in this block, the test being the same as in No. 6 block. The author's notes on this test are the same as in the previous case.

Block No. 8.—Placed on foreshore at Bridlington, on July 29th, 1908, found on Nov. 24th, 1908 (16 weeks and 6 days). *No corrosion.*

Block No. 9.—Three pieces of steel, slightly orroded, were inserted in this block, and the latter was placed in water after a 48 hours' set, and kept in water for 11 weeks and 5 days. In one of these pieces of steel new corrosion is visible ; this, in the author's opinion, is accounted for by the fact that the piece of steel referred to was very near the surface of the block, and it will be also noted from the foregoing table that the aggregate in this block consists chiefly of small slag, which in the author's opinion is most unsuitable for concrete that is to be in contact with water.

Block No. 10.—In this block two pieces of fairly clean steel were inserted, which had been dipped in linseed oil ; the rusting on these bars is very pronounced. This block remained in air for 11 weeks and 5 days after making ; the concrete contained one part coke breeze, but was very dense and of excellent hardness.

The author feels convinced that the linseed oil coating accounted partly for the corrosion, preventing the cement from coming in contact with the steel, and he also considers that coke breeze is not a suitable material to use in concrete which has to come in contact with exposed air.

Block No. 11.—The aggregate was the same in this block, the steel being dipped in turps. The corrosion is very bad, and in the author's opinion is due to a large extent to the coating, as was the case with No. 10. This block was in air for 11 weeks and 5 days. The concrete was dense and good, although it contained one part of coke breeze.

Block No. 12.—In this block the aggregate was precisely the the same as in Blocks 10 and 11, but the steel was clean, and not coated in any way. The block was kept in air and water for alternate weeks for 12 weeks, and the steel was found to be in a perfect condition. The edges of the steel were filed before insertion, and were quite bright, both before and after testing.

Block No. 13.—The aggregate in this block was the same as in the previous three, the steel bars were dipped in cement grout, and the blocks were kept in water after a 7 days' set for 11 weeks. The steel was in an equally good condition when taken out as when inserted, in spite of the fact that the concrete contained one part of coke breeze.

Block No. 14.—Two pieces of rusty steel were inserted in this block, the aggregate being the same as in the previous four blocks. The block was placed in water after a 7 days' set, and kept in water for 11 weeks. The steel was not coated in any way, and it came out with the rust almost gone. The steel was quite wet when taken out, on account of the porous nature of the concrete.

Block No. 15.—This is practically the same test as in Block No. 14, three pieces of rusty steel were inserted in this case, and the same result obtained.

Block No. 16.—The aggregate in this case was more suitable, consisting of 2 parts broken stone, 2 parts $\frac{3}{4}$ in. slag, 1 part sand, and 1 part cement. Two pieces of clean steel were inserted. The block was kept in air for 12 weeks. The steel was in perfect condition when taken out, there being no signs of rust.

Block No. 17.—Two pieces of clean steel were inserted in this block, the aggregate and tests being the same as in No. 16, the result also being the same.

Block No. 18.—Three pieces of rusty steel were inserted in this case, the aggregate and tests being the same as in Nos. 16 and 17. The steel was very badly corroded before insertion, but when taken out much of the rust had disappeared, which leaves no doubt in the author's mind as to the preserving properties of cement.

Block No. 19.—Two pieces of clean steel, previously dipped in cement grout were inserted in this block, the aggregate being the same as in No. 20. The block, after a 7 days' set, was kept for alternate weeks in water and air for 11 weeks. Slight indications of rusting occurred which the author attributes to two causes: (1) That the concrete was not sufficiently dense. In blocks Nos. 19 and 20 river sand was used, which in the author's opinion is not so suitable for dense concrete as crushed sand or sharp land sand. (2) That where the slight rusting occurred the cement grout appears to have been rubbed off, the bare metal being visible. This might occur in handling these bars if the grout had not properly dried on to the bar.

Block No. 20.—The aggregate in this case consisted of 3 parts slag, 2 of sand, and 1 of cement. Two pieces of clean steel were inserted, each being previously dipped in cement grout. These blocks were placed in water after a 7 days' set, and kept in water for 11 weeks. The edges of the steel bars were filed bright before the bars were inserted. No corrosion occurred, the edges being just as bright when the steel was taken out of the blocks as when it was inserted.

Test No. 21.—This is a somewhat interesting test. A reinforced concrete lintel made by the Chain Concrete Syndicate, of Leeds, 10 months ago, became broken in moving, and had to be replaced. It has remained in the open yard of the above company ever since. It was broken for the author on October 13th, 1908, and the two steel clips, which projected out of the concrete for about two inches, were taken out, and the author found that the rust occurred exactly on the line of the concrete face. The preservation of the portion of steel in the concrete was perfect, no rust whatever having occurred, although the lintel has been out in all states of the weather.

Notes in General.—No absolutely bright steel was used by the author in these experiments; what is called "new" steel, refers to the dark mill colour, a sort of blue.

Again, the concrete used in these blocks was in no way specially prepared, in fact, in some cases it was rather carelessly done, with a purpose, namely, to make the test more severe.

Conclusions arrived at.—The results of the foregoing experiments have led the author to the following conclusions:—

(1) That rusty steel embedded in concrete will in a very short time become bright, regardless of whether the concrete is in water or air. This point has, in the author's opinion, been conclusively proved by his experiments.

(2) That the application of cement grout to steel is an effectual safeguard against corrosion, but that the greatest care should be taken in the grouting process to see that every portion of the steel is well coated, and that before the steel is embedded in the concrete the cement grout is allowed to become quite dry upon the steel.

(3) That if the aggregate used for the concrete is not porous and the concrete is well mixed, the reinforcement being well

embedded, no cement coating is needed. This is proved by Test No. 21. (Seeing that the application of a coat of cement grout is such an inexpensive procedure the author makes it a rule in carrying out work of this kind to have all reinforcement coated in this manner.)

(4) That no porous materials, such as coke breeze or slag, should be used in connection with reinforced concrete work, if such concrete is intended to be under water or exposed to the air.

(5) That linseed oil or turps or probably any other coating except cement or lime applied to steel before its insertion in concrete facilitates rather than prevents the rusting of the metal.

(6) That it is of great importance to see that the reinforcing steel is well embedded in the concrete, so that every portion of it is covered with cement.

(7) That the best results were obtained when the aggregate consisted chiefly of broken stone or brick bats. Gravel would no doubt answer as well.

The author was surprised that such a good result was obtained with an aggregate composed of brick bats.

(8) That river sand, generally speaking, is not satisfactory for reinforced concrete work, where such work is required to be watertight.

The author ventures to think that the conclusions which he has arrived at are of great importance, and should ease the minds of those engineers who up to the present time have had considerable doubt regarding this matter ; he also hopes that the attention of the Local Government Board will be drawn to these experiments, and the conclusions arrived at, and that this will result in the period for repayment of loans for work of this class being considerably extended.

He would express his indebtedness to the Chain Concrete Syndicate, of Leeds, for allowing the tests to be carried out at their works, and more particularly to Mr. A. Mitchell, one of the partners in that firm, for the valuable assistance which he rendered to the author in the carrying out of these tests.

Discussion.

The President, in proposing a vote of thanks to the author, said that they had listened to a most important paper on a most important subject. He was sure that the meeting would agree with him that their thanks were due to Mr. Matthews.

The subject of reinforced concrete was one which was very much before engineers to-day, especially those who were engaged in constructive works. The attitude which had been taken up by the Government departments, particularly the Local Government Board, had, to a certain extent, hindered the use of this material in carrying out public works for municipal undertakings. He ventured to think that that attitude was well founded, but, in spite of it, the use of the material was continually extending, and, therefore, it was important that they should have definite results laid before them with regard to the behaviour of the component parts of the reinforced concrete. Mr. Matthews had pointed out the danger of using anything but the best materials in the aggregates. Personally, he (the President) should hesitate before using either slag or cinder concrete in connection with steel. Those who had had experience of the effect of cinders on water-pipes laid in them would know that the cinders had a actively corrosive effect.

With regard to coating bars before they were put into the concrete, the author had shown that the process might be a source of weakness. The cement part of the concrete was undoubtedly a good preservative material. He had used it in connection with the coating of steel buoys in salt water, which would probably be as much subject to corrosive action as anything that could be found. He had found it very useful to put a coating of cement grout on the steel, and then put over it a coating of tar or some other material with which the cement was mixed to protect the steel from the salt water.

The experiments described in the paper had been carried out under a great variety of conditions, and he had no doubt that the speakers in the discussion would be able to give similar data. Engineers wanted all the facts that they could get as the result of observation under the greatest possible variety of circumstances.

The vote of thanks was unanimously agreed to.

Mr. C. F. Marsh, in opening the discussion, said that in his opinion the most instructive experiments were those of the German engineers. Beams were tested with a load, and the reinforcement showed no sign of rusting until it was stressed beyond the elastic limit. In some cases where no rusting occurred the metal was stressed very nearly to its elastic limit, and, consequently, there must have been some cracks in the concrete. The mixture which was forced into the casing around the beams was of a very corrosive nature, and if there had been any chance of the steel being affected it would have been affected by that mixture. He thought that a good test would be to subject a beam of reinforced concrete to a load until the first crack appeared and to leave it under this load between high and low tide so that it would be wet and dry alternately for, say, eleven or twelve weeks, or even a year. That would be practically a conclusive proof of whether the steel was affected.

The coating of steel with linseed oil would only tend to destroy the adhesion which was an extremely necessary property for reinforced concrete, and he did not think its use advisable, even if it did protect the steel slightly from corrosion.

The testing of blocks 14 and 18 showed how the rust disappeared from steel when it was embedded in properly made concrete. He had often noticed the way in which the rust disappeared from steel, and in specifications drafted by him the steel was always permitted to be rusty so long as there was not any loose rust upon it when it was embedded.

As regards covering the reinforcement with cement grout, he had had the impression until recently that it was good to coat the rods with grout and allow the grout to dry before the rods were put in, but he had come to doubt this, for the reason that the grout quickly dried on the steel and tended to peel off, thus destroying the adhesion when the rod was embedded.

The main thing for preserving steel was to embed it in properly made concrete which was not too dry. He was convinced that in many cases where the steel had shown signs of rusting, the corrosion was due to the concrete being a rather dry mixture. The general tendency of practice now was to use a somewhat wet mixture, so that the concrete might thoroughly surround and protect the bars.

Mr. H. D. Searles-Wood said that there was a great deal of doubt about the rusting of steel reinforcement in concrete, but he thought that that had arisen to some extent from the failure of expanded metal to resist oxidation when used in place of wooden laths for plaster ceilings, and so forth.

He presumed this was because the metal was only very partially covered, and he thought that where expanded metal was used in reinforced concrete it might be liable under certain conditions to fail in the same way.

Mr. Bertram Blount said that he had learnt a great deal from the author's paper. It seemed that engineers had begun to understand, concerning the decay of materials which they used, that such matters were under the purview of the chemist. It was somewhat informative to him to find at this date that any engineer doubted that steel, whether it had a scale on it, or whether it was perfectly clean, or whether it was rusty, was permanent when in contact with an alkaline solution, as it must be whenever it was in contact with cement. That was so fundamental that all discussion afterwards, if that was once admitted, turned upon the question whether water could get to the steel core, or the metal, without becoming alkaline. In ordinary cases it was impossible if the concrete was reasonably impervious. Everything that came into contact with the steel must contain some lime, and the steel, as Mr. Matthews had found, would resist any other attack. If, on the other hand, there was a large gap, the conditions became more complicated, and he was not prepared to pronounce upon the future of the steel. Each case must be examined by itself. It was satisfactory to know that crevices and gaps in properly constructed reinforced concrete were not numerous, and that, consequently, the chemical protection which he had mentioned would suffice.

He should like to add a rider to that by saying that he believed in the conclusion which was drawn by the author and endorsed by another speaker to the effect that, if the aggregate was unduly porous, there might be trouble. He meant porous in the sense that it let the liquid through, and porous also in the sense that it kept the cement itself away from the only material that they had to consider at this moment—the core of steel. Consequently it followed, as had been found by those concerned in reinforced concrete construction, that the concrete must be particularly good and particularly dense, and thoroughly in contact with the metallic core, which was used for the reinforcement ; and he believed that if these elementary principles were observed, and if the underlying fact was kept in view—namely, that iron was not likely to suffer oxidation if it was in an alkaline medium—all doubts as to the stability of reinforced structures would disappear.

Professor Henry Adams said that he was sorry that the experiments recorded were comparatively few in number, and that so short a time was allowed for getting the results of the tests. Although the Local Government Board said that fifteen years was the period to be allowed for reinforced concrete structures, engineers looked to a period of fifty or one hundred years, and eleven weeks was almost a microscopic time for results.

It would be, perhaps, a little unfair to the author to cross-examine him about his quotations, but there were one or two points which he should like to know more about. Professor Newbury, in a passage quoted, said that " Water holding carbonic acid in solution, if free from oxygen, soon acts as an acid, and rapidly attacks iron." There was something doubtful, however, in that description, because neither water nor carbonic acid can be free from oxygen. In the following line it was said, " In lime-water or soda solution the metal remains bright." This reminded him of the practice of the Sheffield grinders. After grinding any ironwork they dipped it into a pail of lime-water, and then threw it on one side. The lime water, although weak, was quite sufficient to prevent the material which they were grinding from rusting. A slight rusty colour might show after some days' interval, but this could be wiped off by the hand.

Then Mr. Norton, of the Massachusetts Institute, spoke of corrosion found in cinder concrete : " The corrosion found in cinder concrete is mainly due to the oxide of iron or rust in the cinders, and not to the sulphur." In the very next paragraph he said, " Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel." So there seemed to be two opposite opinions given by the same man. In one case he said that the steel should be clean when laid in the concrete, and in another place he told them that it did not matter, and that it was rather better that it should be a little rusty when it went in, because it would come out bright. This showed the importance of having actual tests which were carried on with sufficiently minute observation,and for sufficiently long periods.

The German tests were particularly interesting, because they showed that only those beams that were stressed to more than thirty-five thousand pounds to the square inch showed any rust in the steel. The concrete had probably opened in minute cracks, and the carbonic acid gas (carbon di-oxide) and moisture had penetrated the cracks to the steel.

With regard to grouting, or painting the bars with grout, he believed that the grout should not be allowed to dry too much before the bars were embedded in the concrete. Lime, put on in a similar way, rubbed off, but did not scale off. Cement either held on very tightly, or came off in a clean scale when it was dry ; it was less likely to come off, and formed a better key if it was only just drying when it was embedded in the concrete. Iron chains had been spoken of—the iron chain round the dome of St. Paul's, and that in the concrete sea-wall at Bridlington. That was an old-fashioned and extravagant method of reinforcement, because the metal doubled upon itself, and so gave a very great weight in a short space, but only the two side sectional areas availed for strength. Straight bars were much more economical.

With regard to Block No. 1, mentioned in the paper, the author said that when taken out it had improved considerably in appearance, and he found that the pitting had been " considerably arrested." That, he supposed, was the author's opinion, but it appeared to be without any direct evidence, and could only be founded on general observation. It did not seem quite definite enough.

The author spoke of the aggregate of the concrete being " porous " or " not porous." He (Professor Adams) was not sure what the author included in that term, and whether he regarded stone and brick as porous. Of course, flint ballast was not porous, and he presumed that coke breeze only could be considered porous in this connection.

The author had made an objection to the use of river sand, which was a common complaint. He (Professor Adams) thought that the reason was that it was often too fine for good work. Good, coarse, clean pit sand was generally believed to make the best work in reinforced concrete.

Mr. H. Ellis Hill regretted that his experience of ferro-concrete had been very slight, but he assumed that ferro-concrete should be made more or less like other good concretes. They spoke about coke breeze and slag concrete, but he presumed that no engineer who wanted a strong and sound material would use either one or the other without iron or steel reinforcement. If they wanted a strong ferro-concrete they must have strong concrete to begin with.

With regard to coating steel bars with cement wash for protection, that was well known to shipbuilders. In building a ship, they would coat the bilges over with cement wash, and what protected steel in one case would have the same effect in another. When forming cement or ferro-cement beams, instead of coating the iron, in which case the coating dried or scaled off it would be well in ramming round the concrete to ram in, if possible, some finer or richer concrete just where the bars were placed, which would act both as a coating and a tie to hold the concrete to the iron.

It seemed rather strange that in some cases where rusty steel was put in it became bright. If that were so, what became of the rust ? Assuming it to scale off, one need not go to any trouble in the first instance to clean the metal. After all, ferro-concrete, like all other concrete, unless it was well made under careful supervision, would be a failure.

Mr. Wells said, in reference to Professor Norton's experiments extending over three weeks, that if they had extended over three years the results might have been different. Whether the test was with concrete or neat cement, or 3 to 1 sand briquettes, a period of four or five years ought to elapse before any definite result could be come to. Professor Norton's conclusion with regard to his first experiment was that neat Portland cement, even in thin layers, was an effective preventive of rust ; but that was not the case unless the steel was covered with concrete within two or three weeks. He (the speaker) had found that where steel had been covered with cement grout it invariably oxidised under the grout. He was of opinion that cement grout should never be put on steel which was to be used as a reinforcing material. He never permitted it himself, but when possible, he had all the bars slightly rusted before putting them into the concrete. He had made an experiment which bore upon the subject of corrosion in breeze concrete. A beam 14 feet 6 inches span by 6 inches thick, of very evenly graded concrete mixed in the proportion of 4 of breeze to 1 of washed Thames sand and 1 part cement, and reinforced with $\frac{1}{2}$in. round steel bars spaced 4 inches apart, was left in the open air for about twelve months. Six weeks after it was made the centres were struck, and a deflection of half an inch took place, owing to the concrete being too elastic. This beam was exposed to the weather for 12 months and then broken up, when every rod in the concrete was found to be rusted from end to end, and in some cases very badly pitted. That was sufficient to show that breeze should not be used in reinforced concrete construction, Again, about two and a half years ago he was recommended to use clinker from the Liverpool destructor, as it was said to be an excellent material for concrete. He obtained some, and used it in 5 to 1 concrete. The seven days crushing result averaged 193 tons a square foot. At the end of twelve months he observed that one of the cubes was "blown" on four faces. When he put it under the crushing machine it failed at 123 tons a square foot, as against 193 tons at seven days.

With regard to the rusting of steel in concrete under water, he would quote the case of the Effra and Clapham storm relief sewers, built on the Thames foreshore, and uncovered during the reconstruction of Vauxhall Bridge. The sewer was covered with 12 inches of 6 to 1 concrete, and in the centre, at 6-ft. intervals, were embedded some 1½-inch round bars. They had been covered by the tide for four hours twice a day, during a period of twenty years. The water had got into the concrete, but when the rods were taken out they were perfectly bright, whereas, where the rod had passed outside the concrete its sectional area had been reduced by one half owing to oxidation. He would have liked the author to state what was the degree of fineness in the cement. He (Mr. Wells) thought it might be somewhere between 6 and 9 per cent. on a 180 by 180 sieve, with about 72 per cent. of flour.

It was a very great mistake to coat steel rods with boiled oil or turps. With regard to river sand, he had always found it perfectly satisfactory for reinforced concrete work, but that depended upon the place from which it was taken. Sometimes it was exceptionally fine, and then it was necessary to add a coarser material.

Mr. D. B. Butler said that there was no doubt that with a well made concrete, not too porous, and composed of proper materials, the reinforcement was perfectly good for any length of time, but he must say that the author's test of eleven weeks was too short a period for a conclusive experiment. He understood the President to say that he had met with concrete composed of breeze and clinkers, which had caused very serious corrosion in water-pipes laid in such material. A notice appeared in the technical press a short time ago, of an edict issued by the German Government forbidding the use of breeze or coal residues for concrete ; if that was so, it seemed that they had found such materials to be unsuitable for concrete, and more especially, for reinforced concrete. There had been a good deal of discussion as to whether the reinforcing rods should be washed with cement grout before they were put into the concrete. It seemed to him that, by coating with cement grout and allowing it to dry, they would only prevent the concrete adhering to the rod, because the grout, after drying, became a scale, and chipped off, more or less, on being put into place. The better way was either to put it in wet, or to see that the concrete was in complete contact with the reinforcement. A short time ago he investigated the failure of some reinforced concrete piles. The piles were allowed to harden for some months before driving, and when driven, they splintered and split. On examination, it was found that not more than about 20 per cent. of the surface of the reinforcing rods was touching the concrete, owing to the latter having been rammed in so dry. The whole object of the reinforcing was therefore nullified. With regard to cement analysis, he had had very great experience, but had never yet found an analysis like that given in the paper, in which the alumina was 9·10 per cent. and the iron only 1·95 per cent. It looked to him as if the analysis was scarcely accurate. The percentage of iron with 9·10 per cent. of alumina would, as a general rule, in English cement, be nearer 2·95 or 3·95. Coating the reinforcing bars with oil and turps was worse than coating with cement grouting, for it altogether prevented the concrete from adhering to the bar, and the protection it might afford against rusting was very problematical.

Mr. Matthew Garbutt said that as, in this country, buildings are usually required to last for at least the term of an ordinary 99 years lease, it was of importance to know what would happen to their materials in the course of this period. In ferro-concrete the time the material would last and the amount of covering given to the steel were intimately related factors. It was stated in the paper that the cubes experimented upon were 8 inches square and that in some cases three rods were put into one cube. Perhaps the author could say what thickness of cover the metal received.

The periods covered by the author's tests were, unfortunately, short. Where longer terms were referred to, as, for instance, in the case of the chains in the sea-wall and that in St. Paul's, the metal was embedded in some feet of concrete, the cover being so great that the protection was practically perfect. This amplitude of cover was, of course, far greater than was usual in concrete buildings. Reinforced concrete was so far a new material for general use that there had been few opportunities of making records of its behaviour during long periods of years, and therefore every available example was of interest. He had had an opportunity of seeing rather more than a hundred blocks containing iron rods which had a covering of about 1 to 1½ inches. They were broken up at an age of a little over twenty years, and the concrete was very good. Some rods were quite free from rust, but others showed distinct rusting. Very often the cracks in the blocks which covered the rusty bars were so fine that they could not be detected by the eye. These blocks had not been subjected to any appreciable tensile stress, and so the cracks could not have been due to tension. They might be, and their direction would indicate that they were, due to expansion when the iron had begun to rust. As to the use of expanded metal, he did not know why the metal should be any worse in that form than in the form of rods, provided that it received good cover, but he certainly had seen cases where it had been unsatisfactory. He instanced an example where expanded metal was placed in a slab about 3 inches thick, the average cover being about an inch. Within twelve months the pattern of the mesh of the expanded metal could be seen in rust stains on the inside of the slab, the outer side being very fully exposed to the weather, and painted.

The question of small cracks was an extremely important one, and many persons interested in ferro-concrete works contended that when those cracks were extremely fine they did not matter ; but it seemed to him that, however fine a crack, if they gave it time it would admit water if there was any exposure to the outer air.

Mr. R. W. Vawdrey said that he had recently had before him a paper dealing with the International Navigation Congress held at St. Petersburg last year, in which the question of the permanence of concrete was very fully discussed. One or two instances mentioned at that Congress might be of interest. Mr. W. T. Douglass mentioned that in 1884, when the Eddystone Lighthouse, originally constructed in 1757, was taken down, a bundle of rods which had been accidentally left in the concrete in the centre of the lighthouse was in perfect condition. That was an experience of one hundred and fifty years or thereabouts, and during the whole of that time the lime concrete had been exposed to the action of sea water, which would, of course, give the very worst results, and yet, owing to the rods being embedded in the concrete, they were found perfectly bright when taken out. Again, Mr. Colson, of the Admiralty, mentioned the pulling down of a masonry wall from 150 to 200 years old, built with mortar ; what kind of mortar was not stated, but he (the speaker) imagined that it was lime mortar. Several large iron nails which had been accidentally left in the wall were taken out quite rustless. Of course, in both cases the depth of the embedding was considerable, and in that respect they differed from modern reinforced concrete structures, where the covering of the steel would be a matter of an inch or so.

Other experiments were described at the Navigation Congress which bore upon the point mentioned by Mr. Marsh—the testing of the beams under water with the object of cracking the concrete, and finding whether the water affected the steel. M. Wortman tested a beam under sea water for two years, keeping the beam between high and low tide, so that it was alternately wet and dry. The steel was stressed nearly to the elastic limit so that the concrete was cracked, and that condition was kept up for two years, the load being kept on the beam for the whole period. The beam was then removed and broken up, when the steel was found perfectly clean.

An instance had occurred in his own experience where concrete on expanded metal was used in covering a sewage tank. The tank contained a sludge elevating arrangement, the sludge being deposited on the roof four times a day. The concrete of the roof of the tank was an ordinary good class of concrete, but he found that it was not water-tight. The moisture from the deposited sludge dripped continually through the concrete, which was thus shown to be porous. When the expanded metal was put into the concrete it was thickly covered with rust, but when, eighteen months after, he had occasion to cut a small manhole in the roof, the piece of expanded metal, about three feet square, which was then removed, was perfectly bright.

To revert to the Navigation Congress, it appeared to be generally considered that cement concrete in sea water was liable to very severe deterioration. All the engineers who reported to the Congress made that point, but there were also certain means recommended for preventing deterioration of the concrete, such as the addition of some volcanic material. It appeared that it was the lime in the cement which was attacked by the sea water, and that the deterioration of the concrete was stopped by adding any material which would chemically fix the lime. In all cases that were reported, if the concrete itself had not deteriorated, the steel was well preserved, but if it had deteriorated, and allowed exposure to the action of the sea, the steel was badly rusted.

Other instances were given, particularly the case of the Spree Canal bank coverings, which were found to be perfectly satisfactory eleven years after construction.

He should like to endorse the opinion of a previous speaker, that it was unnecessary to coat the reinforcement with cement before putting it into the concrete. He thought the best plan was to free the iron from scale with a wire brush or by tapping with a hammer. But when the bars were in position it was a good plan to pour grout over them, and then add the concrete. The grout worked up through the concrete, and ensured the steel being properly covered.

Mr. B. J. Belsher said that the hesitation of engineers with regard to the use of ferro-concrete in building was perhaps not altogether due to fear of rust ; it might have been originally caused by the collapse of certain structures in America. The author's tests had only occupied a short time, but at least a trace of rust would have been in evidence at their conclusion if rusting was going to take place at all.

A lot had been said about rusty steel becoming bright, after being embedded in concrete. His own experience was that the steel should be allowed to become slightly rusty so as to get rid of the millbloom, and then wire-brushed before the concrete was put around it, the concrete then being stirred up and down around the steel reinforcement, as was done against the casing, in order to work the finestuff against both the steel and the casing. If they trusted to the concrete adhering to the rust, and the rust being simply in contact with the steel, they would not get the necessary adhesion between the concrete and the steel, and this seemed to be the result when the concrete took the rust off the steel. He objected to coating the steel with cement grout ; a far better adhesion was obtained by putting bare wire-brushed steel in the concrete without any coating.

He did not think that either coke breeze or slag was very suitable for reinforced concrete, but well vitrified clinker, broken and mixed with a sufficient quantity of cement to entirely fill all the interstices, gave a perfect concrete, suitable in every way for protecting steelwork from corrosion. He had constructed ferro-concrete floors with clinker (which made as strong an aggregate as any other material, and stronger than ordinary brickbats) ; but the clinker had been very carefully selected, and thoroughly vitrified. If it contained any unburnt cinders, coke, or slag, or if there were too much fine stuff, it would not be suitable for the purpose.

Everyone would agree that to coat steel with linseed oil or turps was a mistake. It was practically equivalent to coating it with soft soap, as was usually done to prevent the concrete adhering to the casing. It was of the greatest importance to have sufficient adhesion between the reinforcing steel and the concrete in which it is embedded.

He did not agree with the author that brickbats made a good aggregate for protecting steel from corrosion. He had once had to pull down a large temporary retaining wall built around stanchions, and although the wall had been built in well proportioned cement mortar, the stanchions, when uncovered, were found to be very rusty.

He did not agree with the author's remark that river sand, generally speaking, was not satisfactory for reinforced concrete where required to be watertight. He had no hesitation in using river sand, and considered it better than a sharp sand for cement concrete. When making ordinary lime mortar it was required to be porous, in order to let the carbon di-oxide from the air find its way into the mortar to complete the setting properties of the lime. Then a sharp sand was used because it made the material more porous ; but when using hydraulic lime or cement which did not require any action to complete the setting, apart from that of the water with which the ingredients were mixed, he thought river sand more suitable than pit sand.

He did not think that nowadays the Local Government Board, or any other public department, believed that a reinforced concrete building was not as permanent as any other building, for they all knew that the new Post Office Buildings were being erected of reinforced concrete, and he thought this was conclusive evidence that all the old prejudices against reinforced concrete were removed, as far as the great public departments of State were concerned.

Mr. G. J. Fenwick said that the author spoke of coke breeze and slag without giving analyses of the materials used. Anyone who had much to do with those aggregates knew that one sample of breeze was very different from another, and results obtained on one sample might be negatived by another ; the same being the case with slag. Sulphate of lime was often present in considerable quantity in these aggregates, the fine dusty material being sometimes excessively rich in that constituent. As they knew, calcium sulphate (plaster of Paris) would attack iron and steel very readily, and that might explain why coke breeze and slag aggregates had permitted corrosion of the steel.

With regard to the disappearance of the iron oxide from the specimens, did it not seem likely that it disappeared during the process of laying the iron in the blocks ? The author started with rusty iron and concrete, and the two were put together and examined after several weeks. There was nothing present in the aggregate of the cement which would react chemically on the oxide of iron and reduce it to the metallic state. If concrete could decompose oxide of iron, as suggested, he should expect to see the ferric oxide in the aggregate also reduced.

Mr. F. J. Bacon said that the effect of the iron on the concrete must also be considered. He was driven to make enquiries as to coating reinforcement with cement wash and allowing it dry before putting it into the concrete. When he was going over the General Post Office extension, the clerk of the works told him that they had put up a piece of wall and had had to remove it shortly after, when it was discovered that the concrete for some inches around the bars was very much more difficult to remove than that in the middle of the spaces between the bars. That seemed to show that the iron had some effect, which, for want of a better word, he might call a molecular effect, on the concrete itself. It was probably due to the direct contact of the concrete with the metal, which would be altogether destroyed by casing the metal with grout. He did not know whether there had been any scientific enquiry as to the reason. Whether it was only that the concrete set, in order of time, more rapidly round the metal and less rapidly at a distance from the metal, or whether there was something beyond that—something more subtle—some actual chemical or physical effect of the metal on the concrete which was more than the usual close adhesion of the one to the other—he did not know, and he should be glad if the matter could be explained. The effect of the concrete upon the metal must certainly have some connection with the other effect—that of the metal upon the concrete.

Mr. A. B. Joscelyne wished to say, with regard to the author's conclusions, that no one would doubt that the concrete did protect the steel and obliterate rust ; but, in his opinion, that seemed to dispose of the necessity for the second conclusion. If the concrete preserved the steel and got rid of the rust on it, what need was there to rub and scale the steel first ? The author said that the application of a coat of grout was a very inexpensive procedure. He (the speaker) did not agree ; it was one of those small items which ran away with a lot of money. In many cases it was overlooked in tendering ; whether accidentally or intentionally he did not know, but it made a considerable difference in the price, and in these days of cut-throat competition it was a thing which would tell very much. It was generally accepted that brickbats did not make as good a concrete as ballast, although he had known cases where it had done so.

Mr. A. S. E. Ackermann said that when he was out at the Cape, from 1875 to 1886, he lived in a typical flat-roofed house in Cape Town. The roof used to leak excessively, especially after the long summer drought ; and the procedure in mending the roof used to be to go on to the roof as soon as possible after the rain and while the roof was still wet. One then generally found little swellings about 1 in. in diameter here and there, and these places remained damp longer than the rest of the roof. Each swelling had to be dug out with the point of a sharp trowel ; and, at a depth of about ¾ in. there would be found a tin tack or a bit of a nail, or, perhaps, a whole nail, or something of that sort, which had rusted, swollen, and pushed a little cone-shaped piece of lime mortar out of the roof. The place being washed out with some water, a little bit of neat cement mortar was filled into it, and thus the leak was stopped. The flat roofs were made of bricks covered with lime mortar made from sea shells.

With regard to coating reinforcing bars with oil, many of those present must have made the mistake of trying to paint on a fresh cement-mortar plastered wall. The effect was simply to get an emulsion. The alkali in the cement combined with the oil, and an emulsion was the result, so that it was obviously worse than useless to coat such bars with oil.

Referring to the leakage through the roof of the sewage tank, was Mr. Vawdrey quite sure the moisture was not due to condensation from the contents of the tank below ? Of course, it might have been leakage as well.

Mr. Vawdrey : I think that it was both.

Mr. Ackermann (continuing) said that he did not suppose many of them thought concrete was quite impervious to water.

If they had a large quantity of water continually percolating through the concrete, as there could obviously be only a limited supply of alkali in the concrete, it would become exhausted in course of time ; and as soon as neutrality obtained, the scale would be turned, and acidity would prevail owing to the amount of sulphuric acid in the atmosphere, especially of large towns.

Dr. J. S. Owens said that he thought the author was on the right lines with reference to the rusting ; experiments were wanted. He believed that the application of cement grout was a mistake, for when the iron was thoroughly bedded in the concrete it got a covering of grout, and there was no necessity to give it another.

With reference to river sand, one of its peculiarities was that it very often had an extraordinary uniformity of grain, and he thought that that explained the porosity of concrete made with this material. If they could obtain river sand which was fairly graded and had different-sized grains, they would have as good concrete as from any other sand. It was a question of the nature of the material, not its source.

With reference to conclusion No. 1, he thought it was a little ambiguous, and he could not agree with it. The author said, "No porous materials such as coke breeze or slag should be used in connection with reinforced concrete work." He agreed with part of that conclusion, but not with the reason for arriving at it. He did not think that the objection to breeze and slag was that they were porous. He thought that was demonstrated by the author's own experiments, one of which showed that brickbats made excellent concrete and preserved the reinforcement. That the concrete was porous was also proved by the fact that the iron came away wet. Brickbats were probably more porous in one respect than coke breeze. They would absorb something like 25 per cent. of their weight of water. Coke breeze had the peculiarity that its porosity was not to be measured in the ordinary way, and was more of the nature of isolated closed cavities than of communicating passages and air spaces as in brick. He would suggest two points for the author's investigation. One was that in making further experiments he should include a test as to the porosity of the concrete as distinct from the porosity of the aggregate. The porosity of the aggregate was an important thing, but it was the final porosity which they wished to get at for the present purpose. If the percentage of porosity of each concrete could be given it would be very valuable. He had also in his mind the possibility of the rusting due to coke breeze and slag being electrical. Possibly, it might sometimes be due to irregularities in the composition of the steel making one part electro-negative and another part electro-positive. Some experiments which would indicate whether that was so or not would be interesting. It was a remarkable fact that the aggregate which caused the most rust seemed to possess the most carbon. He did not know whether there was any connection between the two things, and merely suggested further experiment.

With reference to electrolytic rusting, he should like to mention a case he observed on the foreshore at Brighton in connection with the railway from Brighton to Rottingdean. In walking along that railway, he had often noticed a very curious state of affairs. The rails were at about mean tide level and exposed at low water ; they were in perfect preservation except where they were fastened down on the concrete blocks which were bedded in the chalk foreshore, and at every point where they were in contact with the iron holding-down clips on the concrete blocks the rails were almost cut in two by rust. He thought that this was due probably to some electrical disturbance.

He should like to endorse the remarks made by several of the speakers, that eleven weeks was much too short a time for the tests. He said this without wishing to detract from the value of the experiments. In some cases they gave a positive conclusion, but they could not give a negative one, as the absence of rust after eleven weeks would not show that the iron never would rust.

The following written communications were also received :—

Sir Henry Tanner wrote that so far as his experience went he had not found any corrosion of steel in cement concrete even of the coke breeze kind, and his experience had been mainly in that. Three blocks of concrete with steel inside were put in the lake at St. James's Park early last year, and when one was broken recently the steel was found to be quite unaffected. When alterations had to be made in reinforced work his experience was the same, but in these cases the period of observation was short.

Professor Henry Robinson desired to record his appreciation of Mr. Matthews' paper. The author had referred to the fact that reinforced concrete in this country had been regarded unfavourably, owing to the fear that the metal was liable to corrode. The experiences of many well-known experts in various countries (to which the author had referred) showed that that fear was groundless, provided the work was carried out under the proper conditions. He (the Professor) had designed works where reinforced concrete was employed, and had had to investigate cases where it had been unskilfully utilised. His experience enabled him to appreciate the value of the various experiments which the author had carried out. These, with the recorded experiences of others, would tend to remove any prejudice that might still exist. The fact of reinforced concrete being now employed by several of the Government Departments, and by public bodies throughout the country, might be referred to as indicating that prejudice had practically disappeared, and that we in this country no longer remained, as we had done for years, behind the engineers and architects on the Continent and in America.

Mr. Arthur E. Collins wrote that the best experience he had had of the life of reinforcing iron was at Lowestoft, when a brick lock wall about forty years old was being pulled down. It consisted of brickwork laid in hydraulic lime mortar, and was provided with hoop iron bonding. The bonding iron came out of the mortar perfectly clean, without any sign of rust or waste; the portion which was pulled down being between high and low water mark.

Mr. Edward Stead, commenting on the author's conclusions numbered 2 and 6, desired to draw attention to one or two points regarding the attainment of the desired result, viz. :—the complete coating and embedding of the steel in the concrete.

It would appear almost superfluous to emphasise the need of the greatest possible care in the execution of reinforced concrete work, yet he had seen cases where a want of care had resulted in the steel touching the sides of beam forms or arch-face casings during concreting, so that the steel was exposed when the forms were removed.

A practice often resorted to, and which he thought should be condemned, was that of temporarily raising the bottom reinforcement in beam forms and arches on wooden blocks or strips until concrete was packed under them, the idea being to guide the blocks forward or take them out as the concreting proceeded. Where heavy reinforcing sections were used the blocks required considerable effort to move them, and the steel and concrete already in position was liable to be disturbed in the process. Again, where concrete was placed in a wet state it could not adequately support heavy bars, and the forward movement of the blocks allowed the bars to sink lower than their proper position. In this case, something solid being required to support the steel, and the blocks of wood being already in position, there would naturally be a great inclination to concrete them in, thereby necessitating their removal and the filling up of the cavities with mortar after the centering was struck. It was quite likely that, after the centering was removed, access to these places became awkward, and it might be a difficult matter to properly cover in the bars so exposed.

He thought it might reasonably be insisted that no wood should be put into the forms, but that the bars should be supported where required on small blocks of concrete of the desired thickness, and these could then be incorporated in the main concrete. This method was adopted with satisfactory results in constructing the arches of a large bridge in South Africa, on which he was resident engineer. The reinforcement was on the Monier system, the lower grilles being placed 1 inch from the soffits of the arches and blocked up from the centering on 1-inch cubes of sand and cement which were afterwards concreted in. Small stones had sometimes been used for the same purpose, but uniformity was not readily obtained by their use.

Mr. F. E. Wentworth-Sheilds wrote that reinforced concrete had been used in the port of Southampton for the past ten years, and had proved, on the whole, a satisfactory material. But while some structures had stood the test of time well, others had undoubtedly shown signs of deterioration by rusting, especially some of the jetties, which are exposed not only to sea water and damp air, but also to heavy stresses, vibration, and rough usage from the vessels and railway wagons which they accommodate. There were, however, two reassuring features about this deterioration. One was, that where rusting took place to any considerable extent it soon became apparent, by the fact that it first discoloured and eventually burst off the surrounding concrete. The other was that it seemed quite possible to repair it efficiently by breaking away the concrete, cleaning the rod, and recoating it with fresh concrete.

Experience at Southampton had borne out one point which it was difficult to discover from any kind of test block, namely, that rusting was more likely to occur at those portions of a beam or column which were subjected to considerable deflection. It was noticeable, for instance, that rusting might occur on the under side of the centre of a beam, while at the ends of the same beam, the steel would be absolutely clean and dry. The test of time had further shown that the portion of a structure which was immersed in water suffered less than the portion between tides, and indeed it had sometimes been noticed that the portion which was out of water altogether, and exposed only to damp air, suffered most of all.

Practical experience with this building material certainly corroborated many of the author's conclusions, and it seemed probable that we should soon be able to lay down definite rules for the design and construction of reinforced concrete, which, if followed, might give a reasonable assurance of long life to the structure.

Mr. E. R. Matthews, in replying, said that the President had referred to the Local Government Board's attitude, and had stated that the short period granted by the Board for the repayment of loans for reinforced concrete work had hampered engineers in the use of this material ; but he was pleased to say that the Board had recently granted a 27-years loan for a reinforced concrete retaining wall and roof at Bridlington, and this was certainly an improvement on the 15-years period which had been the maximum time granted in many previous cases for similar work. He agreed with Mr. Marsh that the German tests referred to in the paper were most interesting, but did not agree with him respecting the embedding of reinforcement in concrete when the cement grout with which the steel had been coated was wet. It was preferable to embed it when the cement coating was almost dry, the reason for this being that if the coating was wet there was a tendency for parts of it to come off upon the hands of the workmen who are placing it in position, and therefore it would not be so well covered as if almost dry. He supported Mr. Marsh's opinion that the concrete used in reinforced concrete work should not be too dry, in fact it was better when used in quite a plastic condition.

Mr. Searles Wood had made some remarks on the use of expanded metal, and there was no doubt that where this reinforcement was used it should be better covered than was usually the case. One might sometimes see examples of expanded metal reinforcement, where the metal was so near the surface of the concrete that it was possible to trace the pattern of the mesh. This was not at all satisfactory, because all reinforcement should be well protected if corrosion was to be prevented.

With regard to the time taken by the tests, Professor Adams thought this rather short, and would have had it extend to eleven or twelve months instead of eleven or twelve weeks, but there seemed to be no advantage in this, for if steel was going to corrode at all, surely the corrosion would take place before eleven weeks had expired, especially under the trying conditions to which it was subjected in the experiments. If a bar of iron was put into water it began to corrode immediately, and within a week it was covered with rust ; one would have thought that the same thing applied to steel embedded in porous concrete, but this was not so. It seemed as if the water that came in contact with the steel became charged with lime in percolating through the concrete, and lime water, as Professor Adams had pointed out, did not cause iron to corrode. In test No. 21 ten months had elapsed before the reinforcement was bared. A query had been raised as to the pitting in the iron bar inserted in Block No. 1. This bar had been carefully examined, especially with regard to pitting, before its insertion, and a written description made of its condition, and when taken out of the concrete after the test it was scarcely recognisable, the pitting having been considerably arrested, and nearly the whole of the rust having gone from the bar. Answering Professor Adams's question, "porous" concrete included concrete with aggregates of coke breeze, slag, cinders, or any equally porous material. Mr. Wells and Mr. Butler had said that cement grout should never be put on reinforcing steel as it prevented the concrete adhering to the reinforcement, but he (Mr. Matthews) took the contrary view. Mr. Wells's instance of the failure of certain reinforced concrete work only went to prove the contention that on no account should cinders or coke breeze be used in reinforced concrete work. On the other hand, if time had permitted, a number of instances might have been given of iron that had been embedded in good concrete being absolutely bright when taken out, after an interval of twenty to forty years. He could not agree with Mr. Wells that river sand was satisfactory for reinforced concrete work, as it was too fine, and the grains, as Dr. Owens had remarked, were usually too uniform in size to make it suitable for the purpose named. Mr. Butler's remarks on the failure of certain reinforced concrete piles through the concrete having been put in too dry verified the opinion already expressed regarding the use of fairly wet concrete in reinforced concrete work. Mr. Garbutt had requested information as to the depth of covering over the steel bars used in connection with these tests. In some cases the bars were within one inch of the surface, but the average distance from the surface would be about 1½ inches. Mr. Vawdrey's remarks on his experience in connection with a reinforced concrete sewage tank were especially interesting. He had also made the excellent suggestion that, in the construction of reinforced concrete beams, cement grout should be poured over the boxes as the concrete is being put in, in order that the reinforcement may be well embedded and every portion of it covered with cement. Mr. Belsher said that he had used clinkers in reinforced concrete floors, but, as coke breeze, clinkers, and slag undoubtedly contain acids which are likely to corrode the reinforcement, their use as aggregates is not to be recommended.

Mr. Bacon had raised the point, which his (Mr. Matthew's) experience confirmed, that where reinforced concrete work had to be cut away, the concrete that immediately surrounded the reinforcement was removed with much more difficulty than that which was more distant from it. Whether the steel had some chemical effect upon the concrete or not he could not say. Dr. Owens had suggested two good points for further investigation, viz.:—(1) To test concrete formed of various aggregates in order to ascertain its relative porosity. (2) To ascertain whether the aggregates which cause rusting most easily are those which possess most carbon. In reference to Mr. Stead's communication it was far better to support the bars in reinforced concrete beams and similar work on small blocks of concrete, as he had suggested, than to insert blocks of wood; he (the author) had also seen stones used for this purpose, but cement and sand cubes were the correct thing. He agreed with Mr. Stead that sufficient care was not usually taken in embedding the steel in the concrete.

Mr. F. E. Wentworth-Sheilds had stated as his experience that rusting of the reinforcement soon became apparent by discolouration and subsequent bursting of the concrete. It had been argued by many engineers and others that extensive rusting might go on, and not become evident until the structure collapsed, but his (the author's) own experience coincided with that of Mr. Sheilds, that the rusting did manifest itself.

He could not express an opinion on the possibility of efficiently repairing the damage due to rusting by breaking away the concrete, cleaning the rod, and recoating it with fresh concrete, as his own experience had extended only to new reinforced concrete work.

The communications received from Sir Henry Tanner, Prof. Henry Robinson, and Mr. A. E. Collins were also most valuable, as they gave in a few words the experience of these gentlemen with regard to the subject of the paper.

He would conclude by thanking those present for their gratifying reception of his paper, and for the vote of thanks which they had kindly accorded him.

May 3rd, 1909.

EDWARD JOHN SILCOCK, President,

in the Chair.

THE INFLUENCE OF RAINFALL ON THE DESIGN OF SEWERS.

By C. A. Battiscombe.

[member.]

Statistics of rainfall are collected and noted with such care that it has become possible to ascertain the average rainfall of any populated district for the preceding twenty years or more; observations of the rate of rainfall have also been made, but, except in a few instances, without the aid of self-recording gauges.

Since the influence of rainfall on the design of sewers is dependent on the maximum rate of fall rather than on the average quantity which falls during the year, engineers are forced to rely more on the accuracy of their foresight than on proven data, and, although statistics of evaporation and percolation have been collected, the observations have either been made in reference to special localities, such as the fen districts, or have been carried on by private individuals who have not published the results of their experiments.

Rough estimates, based on local conditions, are usually considered to suffice as data for the design of sewers and their overflow arrangements, and although such approximations are generally approved, the very common complaint of leaky sewers offers strong presumptive evidence that the provision for storm water has been inadequate and that the difficulty of making reliable sewers is due to the internal pressure to which they may be subjected rather than to settlement of the foundations.

The ideal of a perfect sewerage scheme is at present impossible to realize, and it is even difficult to see how improvements can be effected until reliable statistics of the increase of flow of sewage in wet weather have been generally collected and the results compared.

One of the factors which complicate the question of the increase in the flow of sewage due to storm water is leakage of the sewers. It is sometimes asserted that when the amount of subsoil water passing into the sewers does not exceed half a cubic foot per minute per mile, or 4,500 gallons per mile per day, the sewers may be considered satisfactory, but that when the leak exceeds that amount the fault should be located and stopped. In the case of a very short line of sewers, no doubt such a leak is negligible, but when the total length of sewers is considerable, or when the sewage has to be lifted by pumping, there can be no question but that such a leak becomes a serious matter, and if allowed to remain will in time cost more than the work of repairing it.

No doubt the difficulty of completely excluding subsoil water from the sewers is enormous, but with improvements in the methods of jointing, and with more stringent regulations in respect to the quality of drain pipes and foundations, it should not be insuperable.

A reference to the report of the Royal Commission on Sewage Disposal will show that while the knowledge of the effect of storms on the flow of sewage is scanty, the study of the aggregate flow of storm water, subsoil water and sewage has been conscientiously carried out, and that more or less accurate results have been recorded.

The study of a chart of the flow of sewage in a leaky sewer reveals its double capacity of sewer and land drain very clearly, and it will generally be found that during the summer months, when the level of the subsoil water has fallen considerably, that the amount of sewage hardly exceeds the dry-weather flow calculated on the basis of the water supply.

Although the infiltration of subsoil water to the sewers is an evil, and to all intents and purposes a constant evil, the increased flow of sewage due to this cause is unimportant compared with the sudden flushes of surface water from heavy storms. The prevention of leaks in the sewers should be constantly kept in mind when designing a sewerage system, but this difficulty is one which must be dealt with on its own merits.

It may not be inapposite to conclude this brief reference to infiltration of subsoil water to the sewers, by remarking that if the permissible leaks in the sewer average half a cubic foot per minute per mile, a community with only one such mile of sewer has to pay for the purification of 1,642,500 gallons of unnecessary sewage per annum ; unnecessary because the subsoil water, if excluded from the sewer, would be uncontaminated and would ultimately enrich the local water supply.

Turning now to the question of percolation, we find that, though intimately connected with that of storm water, it does not materially affect the quantity of surface water passing to the sewer in towns. It is true that in outlying parts of towns, where there are few paved yards, where the houses are far apart, and where there is a considerable extent of garden ground, the amount of rain water absorbed by percolation, is, in normal circumstances, generally equal to that which falls on the given area, but even in such places all the roof water, and 99 per cent. of that which falls on the road, passes to the sewers.

Such places, moreover, though bristling with difficulties of their own, do not present the same difficulties as those of more densely populated centres, where, in these days of impermeable road surfaces, stone pavements, paved yards, etc., practically all the storm water passes to the sewers.

In studying the methods of estimating the quantity of storm water to be provided for, in sewerage schemes which the author has examined on paper, he has noticed that the estimate is usually calculated on the basis of the area of the district, rather than on the actual area from which surface water would pass to the sewers, allowances being made for percolation in accordance with the nature of the soil, slopes, etc.

This method of estimating the quantity of storm water to be dealt with may, in practice, prove satisfactory, but as the sewers are not intended to act as land drains, it seems a somewhat circuitous and uncertain way of making an accurate forecast of the provision required.

Evaporation during the summer months is very rapid, and, though it hardly affects the quantity of storm water, it does indirectly, to a very slight extent, reduce the quantity which passes to the sewers. By freeing the pores of the surface of the roads from moisture it provides a porous covering which must be saturated before water can pass freely over it. If water is poured on to the surface of a dry path or road, at a uniform rate, a certain proportion is absorbed before the excess flows over the surface. The rate of absorption diminishes when the surface has become saturated and then continues almost constant. With a view to arriving at some idea of the minimum amount of water required to prime the surface of various materials, so as to allow the excess to flow off them, the author has made a number of somewhat rough experiments. He finds that clean smooth concrete requires the application of 0·0013 cubic foot of water per sq. yard before water will pass freely over the surface, but that, if the surface is dusty, this amount is appreciably increased. Rough stone, which is to all intents and purposes impermeable, yet absorbs a certain amount of moisture before the surface is wet enough for water to travel freely over it.

It is unnecessary to give the results of the experiments in detail ; the conclusion arrived at was that for the saturation of the surface of a flat stone, or uneven concrete pavement, 0·003 cubic foot of water per sq. yard may be allowed. In summer such surfaces become covered with dust and it is probable that 0·004 cub. ft. per sq. yard would be absorbed.

This amounts to about 20 cub. ft. per acre, which must be supplied before the excess commences to flow away. Macadam road surfaces, being rough and uneven, require to be supplied with an amount of water equivalent to a depth of about $\frac{1}{20}$ inch or 0·0375 cubic foot per square yard before the water will flow off freely, even though the surface has been saturated by previous showers.

These figures are of necessity very approximate and can only be verified by measurements over a large area. The author's experiments have been made on very small areas, the surfaces selected being those of a flint-metalled and a tar-protected road, and although great care was exercised in conducting the experiments, it was found quite impossible to reproduce the conditions of heavy rainfall.

The rate of percolation on roads, after the surface has been saturated, varies with the character of the metalling, but for ordinary macadamised roads the variation is probably too small to be of account.

By the rough experiments referred to above the author has calculated that, exclusive of evaporation, the amount of water absorbed by percolation through a macadamised road, with a saturated surface, is at the rate of 0·004 cubic foot per square yard per minute.

Now these approximations, though requiring verification, are sufficiently accurate for the purposes of this paper, and are given with a view to showing the comparatively small amounts which can be deducted from the total rainfall per minute, rather than for their value as data.

Reliable statistics can, however, be given with regard to the intensity of rainfall during storms. By the courtesy of the officials at the Meteorological Office the author was permitted to examine the " Records of British Rainfall " compiled by Dr. Hugh Robert Mill, D.Sc., LL.D., and the figures given below are quoted from that publication.

It is well known that the average rainfall for the Eastern Counties is fairly uniform and considerably less than that of the Western Counties.

Places situated at a height of more than 500 feet above sea level have heavier rainfall than places below that elevation.

In the year 1906 the minimum rainfall recorded was 18·78 inches at a height of 82 feet above the sea (Colchester), the number of days on which rain fell being 122 out of 365 ; the maximum recorded in the same year was 130·66 inches at a height of 423 feet above the sea (Borrowdale, Cumberland), the number of days on which rain fell being 299 out of 365.

It is true that 200 inches of rain were recorded, in 1906, at Glaslyn, at an elevation of about 2,000 feet above sea level, but for comparative purposes this large rainfall figure may be disregarded.

The rainfall of 130·66 inches in one year so greatly exceeds the rainfall of almost all other places in England that it may safely be taken to represent a maximum for purposes of calculation. It is permissible to assume that the actual time during which rain fell on the 299 days mentioned above did not exceed an average of four hours a day; and, accordingly, that the average rate per hour would be 0·11 in. per hour, an amount equivalent to 0·0014 cubic foot per square yard per minute.

From these figures it is fairly obvious that the average duration of rainfall per day may have been over-estimated, and that the bulk of the rain probably descended in showers or storms which must greatly have exceeded the rate of 0·11 in. per hour.

If the average rate per hour for a maximum annual rainfall is so small, no doubt can be entertained that its influence on the design of a sewerage scheme can have reference only to difficulties which are encountered by the infiltration of subsoil water to the sewers. Statistics of average rainfall may be misleading if wrongly interpreted, for the heaviest storms occur as often in localities of which the average rainfall is low, as in those of which it is high. Hence in investigating the question of the influence of rainfall on the design of a sewerage scheme it is unnecessary to consider the average annual rainfall. The attention must be concentrated on the intensity of the rain storms and the general contours of the area to be sewered.

With this end in view it is desirable to notice a few of the storms which have been recorded recently, and, using them as data, to draw an inference as to the amount of surface water which, under different conditions, would pass to the sewers.

The following storms are selected from the number of those recorded in "British Rainfall" for the years 1905-7. The storms selected are the heaviest, from the standpoint of rate per hour, which fell during the several years :—

Year.	Locality.	Duration.	Rainfall. Rate per hour.
1905	Ponders End, Middlesex ..	19 minutes	3·32 in.
,,	East Liss, Hampshire	20 ,,	2·82 ,,
,,	Huddersfield, Yorkshire ..	30 ,,	3·08 ,,
,,	Sevenoaks, Kent	40 ,,	2·49 ,,
1906	Burnham, Norfolk	—	2·60 ,,
1907	Edenderry, King's Co., Ireland	20 minutes	3·42 ,,
,,	Tedbury (Rochford), Worcester	30 ,,	3·22 ,,
1906	Guildford, Surrey	8 ,,	6·68 ,,
,,	Godalming, Surrey	8 ,,	5·78 ,,
,,	Haslemere, Surrey	8 ,,	4·95 ,,

The storm at Guildford, Godalming, and Haslemere, which occurred on August 2nd, 1906, is so abnormal that it must be disregarded, but it is quoted as showing that heavy storms do not necessarily fall over a very small area.

The other storms recorded, occurring as they do in different parts of England, seem to be of comparatively frequent occurrence, for it must be remembered that, though there are numerous observers of rainfall, few have either the equipment or the opportunity for gauging the rapidity of the fall during storms. It is clear, from the "Records of British Rainfall," that the average rapidity of the fall of rain varies inversely as the duration of the storm, and the question to be decided is :—What maximum rate of rainfall per hour should generally be assumed, and for how long ?

The author does not presume to answer a question which can only be determined by the collection and compilation of a great number of observations extended over a period of several years, but he is of opinion that until accurate statistics can be obtained, the safest, and eventually the most economical course will be to assume that the rate of rainfall which has to be allowed for will equal 3 in. per hour for a period of 20 minutes. He considers that if calculations are based on that hypothesis and due allowances are made for local conditions, the relative merits of different methods of sewering would be emphasised, and that the whole problem could be more satisfactorily dealt with than is possible when the basis for calculation is the estimated total rainfall during a heavy storm.

By taking a simple hypothetical case and assuming, for illustrative purposes, that a single street has to be sewered, either on the combined or separate system, the author hopes to avoid a tedious statement of the several arguments in favour of one system or the other, and at the same time to indicate the methods he employs to arrive at the correct dimensions of the sewers.

The example taken is that of a large village in Yorkshire with a regular water supply. The main street of the village is nearly a mile long and fairly level for about seven furlongs, but falling at a gradient of about 1 in 50 for the last furlong, towards the bank of a stream. The houses at the end remote from the stream are villas and semi-detached villas, numbering 17 in all, and having an average garden frontage of 40 ft. In the village itself the houses adjoin one another. At the lower end of the street, a few cottages are situated at one side of the street. The width of the street, at the end remote from the stream, is about 40 ft. for a distance of about half a mile ; the width increases in the main part of the village, but as it is unnecessary to refer to more than the first half-mile of the roadway, it is useless to give further particulars of the second half.

The water consumption is about 15 gallons per head per day. The estimated population of the entire street is 665, of which 85 people live at the upper end, 530 people in the main cluster of houses, and 50 in the cottages at the lower end of the village. Hence the average dry weather flow of sewage at the end of the first half of the sewer is 1,275 gallons per day ; at the end of the road it amounts to 9,975 gallons per day.

By averaging a considerable number of gaugings of the flow of sewage at different places during the daytime, the author has established the fact that the maximum daily dry-weather flow may be safely assumed at 2·37 times the average flow per minute for the 24 hours.

On this basis, the flow at the end of the first half-mile will be 0·335 cubic foot per minute ; and, at the end of the street, 2·63 cubic feet per minute. Now it is evident that, for this flow only, the diameter of the sewer should not exceed 4 in., but since a considerable increase of population was anticipated in the near future, it was decided that a 6-in. sewer could be put down for the whole length of the street.

To avoid deep trenching in wet ground, minimum gradients were chosen, and resort to flushing was necessary. The gradient selected for the first half-mile was 1 in 160 ; that for the second half-mile was 1 in 120, which severally give velocities at periods of maximum flow of 0·98 ft. per second at the end of the first half-mile and 1·5 ft. per second at the lower end of the sewer. The depth of sewage in the pipe at periods of maximum flow in the first half-mile is so small as to necessitate a considerable amount of flushing.

It may safely be assumed that the total discharge when flowing full, of a 6-in. pipe laid at a gradient of 1 in 160, is 28·56 cubic feet a minute, with a velocity of 2·17 ft. per second.

On this assumption, the total amount of foul sewage and surface water, which, without ponding in the manholes, could be drained away in 15 minutes by a circular pipe 6 ins. in diameter, laid to a gradient of 1 in 160, would be 946·6 cubic feet, of which 518·2 cubic feet would be flowing in the pipe at the end of the 15 minutes.

As a matter of fact, in the case under consideration it was determined to exclude all surface water, but as the conditions are not dissimilar to those which obtain in the approach to many small towns, the question of surface water may be dealt with.

Now, assuming that the maximum intensity of the storm is at the rate of 3 in. per hour, the actual amount falling would be 0·0375 cubic foot per minute per square yard.

Of this quantity, after the first two or three minutes, 0·004 cubic foot per minute will be absorbed per square yard of the road surface, but practically the whole quantity falling on the roofs and paved yards may be assumed to have no outlet but the drains. The area of the roofs and paved yards in the first half-mile amounts approximately to 5,667 square yards. The area of the road on the same section amounts to 11,733 square yards.

After a period of two or three minutes the rain water from the roofs and yards would amount to 212·5 cubic feet a minute, and that from the road, after deducting for absorption, would amount to 393 cubic feet a minute, or a total for the whole area of about 605 cubic feet of water per minute. Thus in a quarter of an hour the total amount of storm water to be dealt with would be 9,075 cubic feet.

Now, various factors have to be considered in reference to the transit of rain water from the houses, and of the surface water from the road to the sewer.

First, then, it may be assumed that the delivery into the house drain from the rain-water pipes and yards is through gratings, but that the flow at such points is checked. As the numbers of these gratings and their dimensions vary on different premises, it is extremely difficult to obtain even an approximate estimate of the total retardation due to this cause, but for general purposes it may be assumed that the number of gratings does not exceed 9 to each thousand square yards of roof and paved yard area. It may also be safely assumed that the width of the openings in the grids is small, and that the total area of the openings does not exceed the area of the house drain to the sewer.

In the case under consideration these assumptions give the following results :—

Each house would be provided with three gratings having openings of a total area of about 12½ square inches, equal to the sectional area of each house drain to the sewer. Owing to friction in the passage of water through the narrow openings in the grids it may be safely assumed that the coefficient of velocity will not exceed 0·67, and that 2 in. ponding will take place over the grids. The velocity of the flow would then be 2·17 ft. per second, and the average delivery of water from each house to the sewer would be 11·3 cubic feet per minute ; or from the total of 17 houses 192 cubic feet per minute. Taking into account loss of head from eddying and shock, the partial closing of the grids by leaves, paper, or other obstructions, and allowing for a total loss of 10 per cent. from these causes, the actual amount of rain water entering the sewer would be a minimum of 173 cubic feet out of a possible amount of 212 cubic feet per minute from roofs and yards during the whole of the latter part of the storm.

As regards the road surface, it is somewhat difficult in a hypothetical case to make a fair assumption of the distance apart of the road gullies. However, on a fairly flat road they might be placed 150 ft. apart, and this distance may be taken for the purpose of these remarks.

The distance between the gullies being 150 ft. and the slope small, it is evident that an appreciable interval would elapse before the gutter could deliver a maximum quantity of water to each gully.

Assuming that the gradient of the gutter is 1 in 200, and that the grids permit all the surface water to pass freely into the gully, then the time which would elapse before the maximum delivery took place would be at least 1¾ minutes after the commencement of the storm.

The rate of delivery of water to the sewers will be equal to that of the rainfall, less the amount absorbed by percolation. The width of the road being 40 ft., the rainfall over the area of road draining to one gully per minute is 25 cubic feet, of which 2·67 cubic feet will be absorbed by percolation through the road material. That is, the amount of surface water passing to the sewer from each grid will be 22⅓ cubic feet per minute during the whole of the latter part of the storm.

Referring once more to the rain water from roofs and yards, it is to be observed that, in the example under consideration, three houses are situated on one side of the road, in a distance equal to that which has been assumed between the road gullies; and that the amount of rain water from these three houses exceeds the amount of surface water which passes into one road gully.

The area of roofs and yards may in this case be excessive, but it seems legitimate to conclude that as a general rule, in a street lined on both sides by houses, the rain water from the roofs and paved yards would equal if it did not exceed the amount which falls on to the surface of the road between them; and that the problem of dealing with storm water becomes, to a large extent, a problem of dealing with two bodies of water, one from an unpolluted and the other from a polluted source. This aspect of the question will be referred to again, but for the moment it is necessary to return once more to the examination of the hypothetical case, in respect to the provision of drains for storm water generally.

It has been shown that the maximum quantity of sewage flowing in the sewer at the lower end of the first group of houses amounts to 0·335 cubic foot per minute, and that the quantity of rain water from the roofs and yards might amount to at least 173 cubic feet per minute during a period of 15 to 20 minutes.

Thus, in a period of 15 minutes the quantity of storm water which must be drained away is 8,495 cubic feet, of which 2,600 cubic feet comes from the roofs and yards of 17 houses, and 5,895 cubic feet is surface water from the road. It has been estimated that the full capacity of a 6-in. drain pipe laid to a gradient of 1 in 160 and for a length of half a mile is 946 cubic feet. Hence it is evident that where the relative quantities of foul sewage and storm or surface water are so disproportionate it would be impracticable to arrange for the combined system of sewering. In the case under consideration a 6-in. pipe is unduly large for the conveyance of the existing quantity of foul sewage, whilst it would be too small to act as an efficient surface-water drain.

The actual size of the storm-water drain required is governed by its maximum discharge at the gradient selected. The total amount of storm water in the first quarter-mile in 15 minutes would be 2,600 cubic feet from the yards and roofs, and 2,948 from the road surface, or 5,548 cubic feet in all.

Assuming a velocity of 2 ft. 6 in. per second, an approximate method of arriving at the diameter of the sewer is as follows :—

Total quantity of foul sewage and storm water in cubic feet .. .. = Q
Approximate area of sewer in square feet .. .. = a
Actual length of sewer in feet .. .. .. = l
Velocity of flow in feet per second .. .. .. = v
Estimated duration of storm in seconds .. .. = t

$$a = \frac{Q}{l + \frac{vt}{2}}$$

$$\text{Diameter} = 1{\cdot}1284\sqrt{a}$$

In this case the area required is 2·22 square feet and the diameter of the pipes would have to be 21 in. The gradient to which a 21-in. pipe must be laid to give a mean velocity of 2 ft. 6 in. per second is 1 in 500.

Since the inclusion of an amount of storm water from the roofs and yards is omitted in the next length, the diameter of the storm-water drain would be constant for the whole half-mile.

The limitations of a paper of this kind permit only a partial investigation of a complicated subject, and many vital points have necessarily to be passed over ; without doubt the difficulties presented by a hilly district are so great and so diverse that a large volume might be written on the subject without exhausting it. The author is fully alive to this fact, and feels that to discuss it in a superficial way would be worse than useless. He therefore omits reference to those points, and draws attention to further arguments respecting the relative advantages of combined or separate systems.

As in the case cited above, it will frequently be found that the relative quantities of foul sewage and storm water are so disproportionate that it is quite impossible to provide a single sewer adapted to the requirements of each.

It may be granted, though, that if a rule for the minimum flow of foul sewage in a sewer could be formulated, the difficulty of arriving at a definite choice between combined and separate systems would be greatly facilitated.

In the author's opinion, the minimum depth of sewage flowing above the invert of a cylindrical pipe during periods of maximum flow should be 1½ in. at a velocity of 1·75 ft. per second, for pipes up to 12 in. diameter, and 1¼ in. at a velocity of 1·5 ft. per second for larger pipes.

Turning to that aspect of the case which is presented by the ultimate disposal of surface water, it is well to bear in mind that, as has been mentioned before, surface water from roads and polluted yards is of a very different character to rain water from roofs and paved yards, which as a rule are kept fairly clean. Surface water from roads, even after heavy rain has been falling for some time, is considerably polluted by filth washed from the interstices of the road metal ; and though after drought the amount of impurities in solution is at first very small, the solvent action of water rapidly liquefies it, and renders such surface water unfit for discharge into a stream used for the supply of drinking water.

On the other hand, rain water from roofs and clean paved yards contains so little impurity, that in many hot countries it is drained into reservoirs and is frequently the only water supply of the house or district. The author himself was dependent on this method of collecting water during a protracted sojourn in South America. So far as he can remember, rain water collected in this manner had no baneful effects ; and the cases of diarrhœa of which he had cognizance were very few and could not always be attributed to the drinking water.

In England itself, isolated coastguard stations, which, it may be added, are models of cleanliness, depend entirely on rain water collected from the roofs for their drinking water, though at these coastguard stations, as a rule, the water is all filtered before being used.

This being the case, a question arises as to why, when considering the relative advantages of combined and separate systems, the expediency of differentiating between a practically pure supply of rain water and a polluted supply does not, so far as the author is aware, receive the attention it deserves. If the Ordnance Survey of almost any town is consulted it will be noticed that the area of roofs approximates to that of the roads adjacent ; and it may be conjectured with some degree of confidence that if the combined areas of roofs and clean paved yards were compared with the area of the adjacent roads the former would predominate.

The great objection to a separate system is that, owing to the polluted character of surface water, the drains provided for its reception become foul, while the storm water conveyed in them is unfit for discharge into a stream without some form of treatment.

Now, if, in lieu of providing a separate system of drains for the conveyance of all storm water, the surface water from the roads passed to the ordinary sewers and the rain water from roofs and clean yards were conveyed away in separate drains, the chief difficulty of dealing with storm water would be lessened. If it be conceded that the pollution of storm water constitutes the leading objection to the employment of a separate system, and the amount renders its disposal a matter of great difficulty, why, it is fair to ask, is the quantity of polluted surface water increased by the addition of, approximately, an equal quantity of pure water ? The answer to this question appears on the surface to be obvious, and is to the effect that the laying of a foul sewage sewer is far more costly than the laying of surface water drains. If the diameters of the sewers were increased to take the road and foul yard surface water, it would appear to be better to increase them yet further, in order to take the remaining portion of the storm water, rather than to incur the expense of a small separate system of surface water drains.

On looking into the matter more closely, however, this answer will be found inadequate, since the difficulties of dealing with storm water depend to a large extent upon the quantity to be dealt with. The cost of either settlement tanks or filters varies almost directly as the quantity of storm water they are capable of dealing with ; the maintenance of such works varies in some degree with their extent ; and in closely comparing the relative estimated cost of a separate system on the old lines (allowing 1 in. of rain per hour on two-thirds of the area drained) with that of the estimated cost of the arrangement alluded to above, it will be found that the increased cost of the latter is not so great as to render it prohibitive. No doubt the latter system has been adopted somewhere, since its advantages are so obvious, but the author has not come across an instance of its application.

Before concluding this somewhat scanty review of one side of a difficult question, the author ventures to summarise the conclusions to which he desires to draw attention :—

(a) The prevention of leakage in sewers is not impossible if adequate provision is made for storm water.

(b) Sewers should never be allowed to act as land drains.

(c) If land drains are required they should be led to a separate and clean storm-water drain.

(d) The minimum quantity of foul sewage, at periods of maximum flow, in sewers of different diameters, should be restricted to a standard limit, for each size of pipe and gradient.

(e) Roof and clean yard drainage should wherever possible be excluded from the foul sewage drains.

Finally, the author must plead for indulgence if, in dealing with those aspects of the question to which he has alluded, his remarks have been, or appeared to be, trite and commonplace.

DISCUSSION.

The **President,** in opening the discussion, said that the conclusion of the author with regard to leakage of subsoil water into the sewers was one which he cordially endorsed. There was no doubt that leakage into sewers was a source of weakness from all points of view, because where subsoil water could make its way into a sewer, sewage would make its way out, and there was therefore, under certain conditions, a liability to pollution of the subsoil by sewage. Further, in pumping schemes the water which leaked into the sewer had to be lifted, and the lifting was a continual source of expense. Where no pumping had to be done, but the sewage had to be purified, the works of purification were overtaxed to a certain extent (particularly if the system were one where contact beds were used) by the increased quantity of water which had to be dealt with. With the percolating system this matter was not quite so important ; but with a contact bed the quantity of liquid which the beds would hold was limited, and if the total quantity to be dealt with were increased it meant an additional number of fillings per day or per week, which reduced the time during which the aëration part of the process could go on. So from every point of view, apparently, leakage into sewers of outside water was to be deprecated, and every effort should be made by engineers to avoid it.

He gathered from the author's remarks that he objected to any process for calculating the quantity of storm water to be dealt with, which took into consideration the total area of the district to be drained. He agreed with the author to this extent, that if one were called upon to design sewers for a town which was already in existence and where there was no likelihood of an immediate growth of population, one might, by going into very careful detail, arrive at an approximate area of impervious surface which had to be drained ; but such a condition of things as he had just mentioned was not that with which one had often to deal. The problem usually presented to the mind of the engineer was the designing of a system of sewers for a district which was not yet built upon, and in considering such a case he had to exercise his judgment as to the extent of building operations in the future, the class of house likely to be built in the neighbourhood, and the future population which the particular sewer he was designing would have to drain. The problem could not be attacked from the point of view of the exact area, at the time, of roofs and yards ; but the probabilities had to be considered. Therefore, one had to determine the total area which it was physically possible would drain into the sewer, and from this as a basis estimate the probable flow-off. This was the real reason why engineers started with the area drained as the basis of their calculations.

The author did not deal with the question of overflows and relieving the sewers when a certain degree of dilution of the sewage had been arrived at. That was a very important point in connection with a combined system of sewers. The Local Government Board, by requiring six dilutions of sewage before overflows were allowed to come into operation, had to a certain extent fixed a standard which was almost universally accepted. He thought that there were very few places where any serious complaint could be made about discharging sewage which had been diluted to the extent of six to one. When designing sewers to take both storm water and sewage, the degree of dilution fixed the size of the sewers to a large extent, and the other necessary factor was the position at which overflows could be made to discharge into streams. Those two factors were exceedingly important, but they did not seem to be referred to by the author at all.

As to the quantity of rainfall which should be provided for, the standard of 3 in. per hour mentioned in the paper appeared to be exceedingly high, and was one which in dealing with anything like a large town would lead to such enormous sewers that it would be practically impossible to construct sufficiently large conduits to take away the water.

He had extracted some particulars from a very able paper read by Mr. Lloyd-Davis before the Institution of Civil Engineers in 1906, which gave a table of the rates of rainfall which had been recorded at the Edgbaston Observatory, Birmingham. During the years 1900 to 1904 there had been rainfalls at the rate of 1 in. per hour on 20 occasions, which extended over 5 minutes, on 9 occasions when it lasted for 10, on 6 occasions when it lasted for 15, on 5 occasions when it lasted for 20, once when it lasted for 25, and once when it lasted for 30 minutes. During the whole of those four years, therefore, there were only two occasions on which rain fell at the rate of an inch per hour for more than 20 minutes, and consequently it seemed unnecessary to provide for 3 in. per hour.

He thought that in dealing with large areas of land and large towns a rate of 1 in. per hour extending over periods of 20 or 30 minutes was quite as much as need be provided for. Even then a very considerable discount had to be made for water which did not reach the sewers within the time during which the storm lasted. There was a certain amount of loss by evaporation and percolation which, according to the author's experiments, was very small. He (the speaker) questioned whether in large areas the figures given by the author were anything like sufficient. Apart from that, there was a considerable amount of lag in time between the actual falling of the water and the time at which it arrived in the sewer. He questioned whether even in purely urban districts where practically the whole area was built over and where the streets were covered with impervious material, more than 75 per cent. of the water which fell actually found its way into the sewer. In suburban districts a greater percentage still was lost and never reached the sewers, or at all events not until long after the first pressure of water had disappeared.

As to the combined system of sewers, he thought that the systems of purification now in vogue helped engineers to a very material extent. For when treating by means of percolating bacteria beds it was found in practice that if the works were designed on somewhat generous lines and the quantity of sewage dry-weather flow did not exceed moderate limits per square yard, the beds were capable of dealing with the organic matter in the storm water and sewage combined up to six times the dry-weather flow, and that it was not necessary to provide storm-water beds of any sort or kind. That greatly helped engineers to provide for storm water, and therefore one of the great difficulties in dealing with a combined system of sewers had disappeared.

Moreover, the householder or owner of the property which drained into a separate system of sewers had placed upon his shoulder the great burden of constructing two separate systems of private drains. This often resulted in complications with connections which were made at a later date, with the result that storm-water sewers had sewage connections made to them and sewage was conveyed to the streams and pollution took place. These were, in his view, strong arguments in favour of a combined system of sewers.

Mr. H. Alfred Roechling said that the following information, which did not seem to be generally known, might be interesting to some of the members. In answer to questions asked by a member of the House of Commons, Mr. Burns had stated that the cost of the Royal Commission on Sewage Disposal, from 1898 up to the 31st March last, had been £56,061, including the cost of stationery and printing, but excluding the cost of accommodation, and that he understood that an estimate had not been framed of future expenditure which might be required. Reckoning the cost of accommodation at £300 per annum, he (the speaker) estimated that the total cost of the Commission up to the 31st March was about £60,000.

The Local Government Board were acting on the recommendations made by the Royal Commission in their fifth report. They advised local authorities to carry out these recommendations, but they had not issued any regulations on the subject.

Coming to the paper itself, the author had done wisely in not laying down any general rules applicable to every case as regarded the combined or separate system or a partial combination of both. He had instead supplied the Society with very valuable information on details the consideration of which as a matter of necessity must precede any formal decision by the engineer as to which scheme he should adopt.

He (the speaker) did not think that it was possible to lay down any definite rules as to when the separate system, the combined system, or a partial combination of both should be employed. The reason why he thought so was that no two cases were alike. The engineer who had to provide a scheme of sewerage for a district had to study the particular features of the locality, and the information given by the author would prove of the greatest service to him in this respect.

The matter of leaky sewers was an important one, but when the author said that in his opinion sewers probably became leaky through over-pressure during heavy rains rather than through subsidence, he (the speaker) could not quite agree with him. If modern pipe sewers became leaky to any extent there was in his (the speaker's) opinion a fault either in the design or in the execution of the works. All engineers knew that sewers could relieve themselves pretty freely at the gulleys or at the open grids of manhole covers, and, therefore, except in very steep districts, the pressure on the sewers could not be very great. With the excellent joints now made for stoneware pipes, some of which stood a bursting pressure of 40 lbs. to the square inch, equal to 92 ft. of head, sewers should not become leaky. He had seen the record of a joint which collapsed at 120 lbs. per square inch, equivalent to 277 ft. of head. He did not think that a little extra pressure in modern pipe sewers which were well designed, well constructed, and well laid, would bring about an excessive leakage.

In connection with the drainage of a country house, he had inserted a condition in the specification that the whole of the drains were to be tested on completion with hydraulic pressure to a head of 10 ft. The builder carrying out the work probably had not provided for this, and thought that the work would be done in the usual way without any supervision He therefore tried to get the client to agree to a modification of the clause. The client, however, very wisely thought that the clause was for his protection, and said that the specification must be carried out. Ordinary cement joints were made, and when the work was tested under a head of 10 ft. there was no leakage after the brickwork in the inspection chambers and the cement in the cement joints had become saturated. This showed how comparatively easy it was with care to make even a cement joint watertight under ordinary pressure.

The author had not mentioned making any provision for the escape of imprisoned air. A sewer might be only a third or an eighth full of sewage, and the rest might be full of air, and if the storm water rose in the sewer and the air could not escape, an air lock would be formed. In one case where no provision had been made for the escape of air a heavy manhole cover had been lifted some 3 ft. off the ground. The pressure of air might do damage, but its escape could easily be provided for.

The author mentioned an allowance for leakage of 4,500 gallons per mile per day. He (the speaker) knew of a case where the provision made was something like 9,000 gallons per mile per day. As in that particular case the length of sewers was something like 30 miles, the total allowance equalled 270,000 gallons per day. If that was multiplied by 365 the result was something approaching 100 million gallons a year. As sewage could not be pumped and treated for less than £5 to £10 per million gallons—for small places it cost more—it would be seen that this allowance necessitated a good deal of expense. An allowance of 9,000 gallons per mile per day seemed excessive, and the infiltration of subsoil water should be reduced to the smallest possible figure.

The author suggested that rain water from the streets should be sent into the foul sewers, and rain from the houses and yards into the storm-water sewers. Some experiments were made in Leicester over twenty years ago to ascertain what was the proportion of rain that fell on the street. The Leicester sewage sewers had more work to do than they could properly perform, and it was thought that they might be relieved of the rain water to some extent. A district in the town was selected and drained on the separate system to the extent that each street was provided with a duplicate storm-water sewer, which was connected with the street gullies, so that only the rain water on the street itself went into the storm-water sewer. Careful observations extending over a considerable time were then made, and the final conclusion arrived at was that the rainfall on the streets was only 35 to 40 per cent. of the total rainfall, the rest falling on the roofs of houses and on the yards.

Another experiment was made by the late Mr. Santo Crimp in Wimbledon. In one district he took the rain water on the streets and on the fronts of the houses into the rain-water sewer, and the rainfall on the backs of the houses and the back yards into the foul sewers, and his experience was that he got only from 20 to 25 per cent. of the total rainfall into the storm-water sewers. It might be taken that in very large districts only about half the total amount of the rain which fell reached the sewers at one and the same time, as the rain from the lower part of the drainage area had run off before the rain water from the upper part of the drainage area reached this spot. He thought that the author had not made that point quite clear ; but it was a very important consideration, and an engineer who did not pay due attention to that point would be liable to make a serious error in his scheme.

He must take objection to the provision of 3 in. of rainfall per hour. It was impossible to lay down a general law of 3 in. per hour to govern the whole of this country. Each case must be dealt with on its particular merits. He had never come across a case where it was necessary to provide for 3 in. of rainfall per hour, and he did not think that it should go forth from that meeting that such a provision ought to be adopted throughout the country.

As to the relative merits of 4 in. versus 6 in. pipes, there seemed to be a notion that a 4-in. pipe, especially for house drains, was better than a 6-in. pipe. The critical time for house drains was not when they had to carry clean or nearly clean water. but when they had to carry water heavily charged with solids. What held good in the case of clean water or nearly clean water did not without considerable modification hold good in the case of liquids heavily charged with solids. In 1893 some experiments were made by the Sanitary Institute on the amount of water necessary to flush water closets. Parallel experiments were made with 4-in. and 6-in. pipes, so that the results could be compared fairly well. These experiments clearly showed that a 6-in. pipe had a greater self-cleansing capacity than a 4-in. pipe, and they further proved that 4-in. pipes ought not to be used for the conveyance of excreta except for short branch sewers.

He admitted a difficulty in following the author's calculations. The author stated : " It may safely be assumed that the total discharge when flowing full of a 6-in. pipe laid at a gradient of 1 in 160 is 28·56 cubic feet a minute with a velocity of 2·17 feet per second." In connection with this he (the speaker) thought that it might be taken that the three formulæ now principally used for ascertaining the mean velocity were those given by Crimp and Bruges, Weisbach, and Kutter, but neither of these gave the results mentioned by the author. He would be glad if the author would kindly say how he had arrived at his velocities, because he might have a new formula. He also had difficulty in following the author when he said, " The gradient to which a 21-in. pipe must be laid to give a mean velocity of 2 ft. 6 in. per second is 1 in 500."

Mr. Battiscombe, interposing, said that the formula he had used was one which he had made himself.

Mr. Roechling, continuing, said that in the formulæ for mean velocities everything practically depended upon the coefficient.

The author stated as his opinion that the minimum depth of sewage flowing above the invert of a cylindrical pipe during periods of maximum flow should be 1½ in. at a velocity of 1·75 ft. per second for pipes up to 12 in. diameter, and 1¼ in. at a velocity of 1·5 ft. per second for larger pipes. He (the speaker) should be very glad to know whether that was a pious wish or whether it was based on experiments, because in the experiments which were made by the Sanitary Institute in 1893 the self-cleansing velocity was about 4½ ft. per second and the depth of flow only 0·8 in. Those figures were quite different from the figures given in the paper. He hoped that if the author had made experiments he would publish them. All the formulæ gave approximate results only. What were wanted were experiments with liquids charged with solids. The Sanitary Institute had made experiments; but, unfortunately, those experiments had not been continued. He hoped that if money was required for their continuance there would be a combination of societies, because the matter was a most important one. Engineers needed definite practical experiments for their guidance.

Mr. H. C. H. Shenton said that at the beginning of the paper the author gave an allowance for leakage of land water into an ordinary system of sewers. He did not quite see the bearing this had on the storm-water question. The remark, " It is sometimes asserted that when the amount of subsoil water passing into the sewers does not exceed half a cubic foot per minute per mile or 4,500 gallons per mile per day, the sewers may be considered satisfactory," seemed to him (the speaker) a very extraordinary statement. In the first place, an allowance for leakage must depend on the size of the sewer. What would be a big leakage into a sewer 4 in. in diameter would be small for a brick sewer of, say, 10 ft. diameter, while for an iron sewer it surely ought not to be necessary to make a large allowance for leakage. He did not see that there should be any allowance of this kind under ordinary circumstances, and protested that in any properly laid system of sewers subsoil water ought not to be present in such large quantities as to seriously affect the comparison of storm water and daily dry-weather flow.

It was quite easy to lay a stoneware pipe without leaking joints, and it was certainly still more simple to lay an iron pipe without leaking joints, and he did not see why there should be any great difficulty in constructing a brick sewer that should be sound. Therefore, he could not understand the enormous allowance for leakage.

Personally, he always specified that stoneware pipe sewers were to stand a water test after they had been laid, in the same way as Mr. Roechling had described in connection with house drains. It certainly ought not to be publicly stated that leakage was inevitable.

With regard to the conclusions of the paper, the author said that the prevention of leakage in sewers was not impossible if adequate provision were made for storm water. Evidently the author's idea was that storm water would produce an internal pressure which might burst the pipe or joints and cause leakage. Personally, he could see no reason why even a full sewer under pressure should fail. If properly constructed it would be quite equal to any pressure due to storm water.

He thought that it was generally admitted that sewers should never be allowed to act as land drains ; and it was also, he thought, generally admitted that if land drains were required they should be entirely separate.

The author stated that roof and clean yard drainage should, wherever possible, be excluded from foul sewage drains. He (the speaker) did not agree with this idea, and he would point out that though yard drainage or roof drainage might be quite clean at the start, yet, that as people were in the habit, rightly or wrongly, of connecting sink wastes, lavatory wastes, and so on, into yard gullies and also into rain-water heads, there could be absolutely no doubt that in course of time the clean-water drains would contain very foul liquid.

Mr. Henry C. Adams said that, in his opinion, the author had attempted to generalise too much upon a subject in which generalisation was impossible. Some people took the report of the Royal Commission, and tried to prepare standard schemes to apply to all districts ; but it was impossible to deal with the matter in this way, and there was still the fullest scope for the exercise of individuality and practical experience.

Figures of daily rainfall were useless as far as engineers were concerned. Self-recording gauges were required, and every municipality should put one down. Considering the vast amount of money spent annually on sewerage schemes, for which rainfall records were so necessary, he thought that the Government might be asked to provide funds so that the Meteorological Office could make grants for the installation of recorders in selected places through the country. Some years ago, when he was an official of the Corporation of Birmingham, the diagrams from the self-recorders at the Edgbaston Observatory were sent in to the Sewers Department every week, and whenever a heavy rain occurred the details were calculated out and tabulated for use. These diagrams were afterwards utilised by Mr. Lloyd-Davies when he prepared his valuable paper which had already been alluded to.

With regard to leaky sewers, he had taken up a good many miles of old sewers, and he had found more often than not that they had collapsed through the pressure of the superincumbent earth. He had not come across any evidence of properly constructed sewers being made leaky by internal pressure. The modern practice with nearly all pipe sewers over 12 ft. deep or thereabouts was to surround them with concrete, and no practicable amount of inside pressure would make such sewers leaky. The author said, " It is sometimes asserted that when the amount of subsoil water passing into the sewers does not exceed half a cubic foot per minute per mile, or 4,500 gallons per mile per day, the sewers may be considered satisfactory." He had seen these figures in three or four specifications, and he had specially considered the wisdom of the clause. The specifications generally had a clause to say that the whole of the works were to be watertight. In a specification which he looked up the other day the clause referring to half a cubic foot per minute per mile said that if the leakage exceeded that amount the whole length must be taken up and relaid. It did not suggest that such a large leakage was thought desirable. He took it that what was intended to be covered were the small leakages which individually were too small to be stopped, but in the aggregate made a big flow. If there was a big leakage in a sewer it could easily be located and stopped.

The figures given by the author as to the amount of rain which flowed off from so-called impervious areas were, he thought, far too high, and they were not proved by facts within his experience.

Sometimes the rainfall to be provided for was apparently based on the gross area of the district ; but, even when that was done, the calculation was first of all based on a measurement or an estimation of the impervious areas of the district. Afterwards it might, for report purposes, be turned into an equivalent rainfall spread over the whole ; but the engineer always had his details so as to be able to prove the accuracy of his figures. The amount of rainfall to be provided for in the sewers was not guesswork at all ; it was based on very careful and accurate calculations.

The author rather doubted the Cumberland rainfall figures where the rain was taken at 0·11 in. per hour for an average of 4 hours a day, and thought that the time had been over-estimated. He (the speaker) did not think that that was so. Mr. Baldwin Latham carried out some experiments at Manchester some years ago, and he found the average rate per rainy hour 0·05 for 3·5 hours per day. At a place in North Wales it was found to be 0·06 in. per rainy hour for 2·6 hours per day.

It must be noted in connection with these figures for the heavy storms that they only occurred over small areas in individual localities spread over the country, and that the chances of a recurrence of any heavy rain in any particular locality was very small indeed.

With regard to providing for rain at the rate of 3 in. per hour for a period of 20 minutes, he did not think that there was any need to go up to such a high figure. It was equal to 1 in. falling in 20 minutes. Mr. Cutler, of Belfast, had made some observations, and he had found that about a third of this was nearer the figure. Mr. Lloyd-Davis had also found the same. From the Edgbaston records, which had been referred to, Mr. Lloyd-Davis had come to the conclusion that the maximum rate of flow in sewers, at any point of concentration, due to rain was proportional to the amount of rain falling in the same time as that occupied by water in flowing from the remotest point in any area to the point of concentration under consideration, after allowing 1 minute for the time of entry if roofs were directly connected to the sewers, and 3 minutes if the water had to run down the gutters.

From the Edgbaston records it appeared that if provision was made for rainfall at the following rates in accordance with the time of concentration in each area, it would only be exceeded once a year on the average :—

Time of Concentration.	Rate per hour.
5 minutes	1·70 ins.
10 ,,	1·10 ,,
20 ,,	1·00 ,,
30 ,,	0·70 ,,
60 ,,	0·50 ,,

A little larger allowance than this should be made so that the sewer would carry off all that was necessary without flooding, except on rare occasions at longer intervals apart than one year.

He did not think that the amount of pure water which could be cut off by separate drains was sufficient to justify the expense of their construction, but if any question of the cost of purification occurred, and it was necessary to do something, probably it would be cheaper to subsidise owners to build rain-water tanks to each house to collect the roof water for the use of the tenants. Clean yards were very difficult things to find in the lower parts of large towns, and even if a clean one was found, a change of tenants might soon result in the yards becoming very dirty. The gullies might be put in the middle of the yard for no other reason than to carry off the rain water, but the tenant was sure to use it for throwing slops down.

Mr. Hugh S. Watson, referring to the author's statement that the estimate of the quantity of storm water to be provided for was usually calculated on the basis of the area of the district rather than on the actual area from which surface water would pass to the sewers, allowances being made for percolation in accordance with the nature of the soil and slopes, etc., said that the author appeared to hold an opinion that had been expressed by Mr. Lloyd-Davis in his paper on "The Elimination of Storm Water," read before the Inst.C.E. in 1906, in which paper it was stated in reference to the Burkli-Zeigler formula, which is that most frequently employed for estimating the run-off, that "the constant for impermeable surfaces was based on the streets alone, and only two variations were given to meet all cases." He (the speaker) was very surprised at the time that that statement should have gone through unchallenged during the discussion or in the subsequent correspondence. Far from the statement being accurate, Mr. Fruhling had assigned no less than nine different values for the coefficient for absorption and evaporation combined, varying from 0·95 for metal roofs to between 0·0 and 0·25 for open spaces. It was very difficult to make any distinction between various classes of roofs and pavements in designing the sewerage systems of towns; but in the case of Milan the matter was simplified by the central part of the old town, which was almost entirely occupied by houses, being taken at 0·70 to 0·90. For the districts adjoining the central part, which had only a few gardens, the figure varied from 0·50 to 0·70; for the new districts, where the houses were surrounded by gardens, from 0·25 to 0·50; and for gardens, parade grounds, and cemeteries from 0·00 to 0·25. Mr. Brix had adopted a very similar method of calculation when designing the sewerage system of Weisbaden. Mr. Fischer had simplified matters still more when designing the sewerage system of Bergen. There he employed the following values:—For steep and closely built areas, 0·90; for the flatter districts, 0·60; for the villa districts, 0·30; and for parks and gardens, etc., 0·15.

In one part of the paper the author said, "Attention must be concentrated on the intensity of the rain storms, and the general contour of the area to be sewered," and in another part he said, "The question to be decided is, What maximum rate of rainfall per hour should generally be assumed, and for how long?" If sewers were designed to carry away the maximum intensity he (the speaker) could not quite see in what way the period of time affected the case. If the sewers were sufficiently large to deal with the maximum intensity during a fall lasting five minutes, they would do it equally well if it exceeded an hour.

Referring to surface water, the author said that, owing to the impurities present, street surface washings were unfit for discharge into a stream used for the supply of drinking water. Surely the water from a surface water drain was usually much cleaner than the sewage which was permitted to escape from any overflow on a combined sewer after being diluted with 6 parts of surface water? The latter must be much fouler, especially as in surface-water sewers the street washings were or could be diluted, not only by the addition of the water off the roofs of the houses, but by water from public fountains and baths, and water used for condensation purposes. He believed that the arrangement fixed by the Local Government Board was that after the sewage in a combined sewer had increased to two volumes, the rest up to six times the dry-weather flow had to be treated in stand-by tanks. Surely if this was so it would be better to treat the whole of the water from the surface water sewers in stand-by tanks, and to make much more use of the surface-water sewers than is done at present by cleaning all our roads with water, and discharging it into them, which would be one way of getting rid of the dust nuisance. In the last part of the paper the author advocated the taking of water from the backs of houses and yards into the surface-water drains. The great objection to the proposal would be the confusion that would arise from the two sets of drains. It was very difficult to keep people from connecting a foul sewage drain with a clean drain. Even when the two systems were quite separate it did not always ensure safety.

Mr. Carle Salter said that as he had been associated for a considerable number of years with Dr. Mill and with his predecessor, Mr. G. J. Symons, in the work of the British Rainfall Organisation, he thought that, in the absence of Dr. Mill, it might not be out of place for him to make a few remarks on the subject of heavy rainfall.

Rainfall depended, broadly speaking, on two factors—one, the movements of the atmosphere, the other the geographical nature of the land on which the rain fell. The proportion in which each of these factors influenced rainfall was governed by the period during which the rain fell.

If the rainfall over a long period, say 50 years, was charted on a map it would be found that the amount falling depended almost entirely on the configuration and exposure of the land, the highest rainfall falling on the highest land, and the lowest rainfall falling on the lowest land, modified by a general tendency in the British Isles for the fall to decrease in amount from the west coast towards the east coast. If the rainfall for a shorter period, say one year, were considered, the same relation would be found to hold good ; but it was less marked. Individual years exhibited individual characteristics, but, generally speaking, the run of the isohyets bore a great resemblance to the run of the average annual isohyets. If a still shorter period, such as a month, were mapped, there would be found to be a tendency to the same relation ; but it was apt to be almost obliterated in some instances. The influence of a single wet day might practically wipe out the relation between the amount of rainfall and the altitude of the land. Again, when heavy rainfall falling on a single day was considered, there was found, as a rule, to be no obvious relation between the configuration of the land and the amount falling ; in other words, the second factor, which he might call the atmospheric factor, was entirely influencing the distribution of rainfall. In studying still shorter periods, such as had to be considered in relation to the drainage of storm waters, heavy rain falling in a few hours, the atmospheric factor exercised complete sway, and the distribution of rainfall had no semblance of relation to the configuration of the land.

The conclusion he would draw from those facts was that, in considering the amount of water which had to be taken away from any drainage area as the result of unusually heavy rainfall, one need not pay any attention whatever to the average annual rainfall at that particular place, because it might be taken as a demonstrated fact that maximum discharges of rain in very short periods of time were as liable to occur in normally dry places as in normally wet ones.

Sudden flushes of rain falling in short periods of time could be divided into two classes. There was the rain which fell as the accompaniment of cyclonic disturbances, which might amount in some instances to as much as 4 in. in a day. In most instances of this kind the rain fell comparatively slowly, and seldom took place within a few hours, but was spread over the greater part of the day. The other kind of rainfall which fell very heavily was thunderstorm rainfall. That was a kind of rainfall which had to be considered in relation to the subject of the paper.

The editors of "British Rainfall" had been collecting statistics of heavy rainfalls for nearly forty years, and there existed a large amount of data bearing on the subject which only needed to be brought together and worked up to provide much more material for basing calculations upon than was at present available in a compact form.

The data could be studied in two ways. The rainfall over the same period of time at a large number of stations might be placed upon a map, and its geographical distribution deduced by drawing lines through those spots with equal falls, thus separating the wetter places from the dryer ones. Or, the heaviest portion of the rainfall falling in a short time might be tabulated, and the results compared in that form. In investigating thunderstorm rains both those methods had been followed out, and the result had been to show that thunderstorm rains always, or almost always, fell in a very local manner. The most intense portion of the storm seldom affected more than a few square miles at the most. An instance had been mentioned by the author in which rainfall of great intensity was recorded simultaneously at Guildford, Godalming, and Haslemere, and it was inferred that the intermediate districts all suffered in the same way. This was by no means necessarily the case, since it was not an uncommon phenomenon for simultaneous splashes of intense rain to occur in the same thunderstorm, separated by belts in which little or no rain fell.

There had been a great deal of discussion in connection with the maximum intensity of rainfall. He was a little surprised to hear that engineers considered that the maximum might be taken as at the rate of 3 in. per hour for 20 minutes. He did not know anything about the application of the figures ; but he could quote a large number of authenticated instances of rainfall at much greater rates. He did not suppose that it was necessary for engineers to provide for the absolute maximum ever known, because that would be out of the question ; but it might be worth while to mention one or two instances. For example, on July 22nd, 1880, at Cowbridge, South Wales, 2·90 in. of rain fell in 30 minutes, at the rate of 5·80 in. per hour. At Wadhurst, on July 29th, 1901, 3·25 in. fell in 55 minutes, which was at a rate far exceeding the maximum suggested, and also continued for nearly three times as long. On July 12th of the same year, 3·63 in. fell in an hour at Maidenhead. Again, as recently as June 4th, 1908, 3·42 in. fell in 45 minutes at Tunbridge Wells. It was reported at the time that in another part of Tunbridge Wells the fall reached 4 in. at the same time, but it was perhaps not advisable to place too great confidence in the latter estimate without proper confirmation. Very intense falls did not affect a large area, but were confined usually to a comparatively small area, intensity of the rainfall diminishing on every side of a central culminating point. The maximum which should be allowed for, therefore, depended to some extent on the size of the drainage area, because if the area were small and a heavy fall of rain occurred it might fall equally heavily over nearly the whole of it, but if the area were sufficiently large it would probably not fall over the whole of it, and for this reason a considerable reduction might be made.

He endorsed the suggestion of a previous speaker that the Government might be approached with a view to obtaining aid in the erection of a larger number of recording rain gauges. There was not half enough information available on the subject. But it must not be supposed that a self-recording rain gauge was merely a device for saving the trouble of reading an ordinary rain gauge, because this was by no means the case. Many people procured automatic rain gauges in order that they might get the work of registration done for them. Self-recording gauges involved a great deal more trouble than the ordinary type, and they were not to be depended upon entirely for the amount of rainfall. An ordinary rain gauge should always be put down by the side of a self-recording gauge as a check upon the results. It was very necessary to insist on that proviso. Many people had fallen into the error of relying too implicitly on the results of self-recording gauges without checking them. But in the hands of a competent observer, many hundreds of which were to be found among the district engineers at work in this country, a good gauge of this type might be made to yield results of immense value to those who were engaged upon the work of designing sewerage systems.

REPLY.

The **Author,** in reply, said that the President had referred to estimating the areas of new parts of towns, but in estimating the areas he (the author) had taken into consideration only the roads and houses.

Overflows had not been alluded to because they came into an entirely separate part of the question.

The testing of pipes had been referred to, but testing was not infallible. Any number of pipes for use in a sewerage system might be tested, and in a large batch one would be found cracked, which would burst the very first time a storm came.

As to the amount of rain reaching the sewers, he had read the paper with a view to getting answers to the question, "What is the amount that does reach them?"

As regards the question of time, he had taken a very short line of sewer so as to eliminate the element of time altogether. That did not apply to a very short line of sewer, but only entered into consideration in the case of a large district.

One speaker had said something about the minimum flow. What he (the author) had stated in the paper was simply his own opinion, and in putting the matter in this way he wished other engineers to answer the question of what should be allowed as the minimum flow in pipes. He thought that no one had answered the question that evening, although it was one which really did require answering, as on many occasions when examining sewers he had found just a mere trickle of sewage passing down the pipe.

He could not help thanking Mr. Carle Salter for what he had said about rain and the amount of rainfall, because he was sure that, although he (the author) might have over-estimated the amount, he was not so far wrong as some of the other speakers seemed to think.

June 7th, 1909.

EDWARD JOHN SILCOCK, PRESIDENT,

IN THE CHAIR.

THE SINLUMKABA (BURMA) FERRO-CONCRETE BRIDGE.

By W. E. HALDWELL, B.A.

[MEMBER.]

INTRODUCTORY.

IN presenting this paper, it is the author's desire to bring before the Society some particulars of the construction of a reinforced concrete bridge in Burma, and the difficulties which had to be overcome in the course of its erection, in the hope that it may prove of interest to the members generally, and useful to the junior members of the Society and to those engaged on similar work. This bridge was erected by the Burma Public Works Department, and carried a bridle road over a river at Sinlumkaba, a military police outpost in the Bhamo District in Upper Burma, close to the Chinese Frontier. It replaced a timber bridge, which had been washed away during the floods of 1907. Hitherto it has been customary to construct bridges in this district of timber only, because they entailed the least initial outlay on account of the abundance of timber in the immediate neighbourhood ; but these wooden bridges were periodically washed away during times of flood, only to be reconstructed on the same old design. Latterly, however, it has been realised that over the larger rivers, which are subject to abnormal rises during the annual floods, more substantial structures are called for.

The following particulars relative to the erection of this bridge will, it is hoped, gain an additional interest from the fact that the Sinlumkaba Mill Bridge is the *first reinforced concrete bridge built in Burma.* The work was started on January 15th, 1908, and was completed on August 31st in the same year, the author being engineer-in-charge during the continuance of the works.

RAINFALL.

Sinlumkaba itself is situated at an elevation of nearly 6,000 ft. above sea level, and the surrounding hills are at an even greater elevation. The yearly rainfall averages about 150 inches. The following table shows the rainfall for the past seven years, and it is to be regretted that the statistics are not more complete; but no reliable information is available for the years previous to 1902:—

TABLE OF RAINFALL AT SINLUMKABA.

	1902.	1903.	1904.	1905.	1906.	1907.	1908.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
June ..	26·17	38·48	33·58	26·92	41·47	25·61	63·60
July .	42·50	30·12	51·23	31·49	26·87	48·50	49·35
August ..	30·24	62·92	30·60	34·40	33·81	33·53	19·34
Total for 3 months ..	98·91	131·52	115·41	92·81	102·15	107·44	132·29
Total rainfall for year	142·21	167·63	155·75	135·39	136·37	155·44	181·10*

* Total up to October 7th, 1908.

It will be seen from the foregoing table that practically all the yearly rainfall occurs during three months in the year, viz., June, July, and August, and it is during these months that the greatest floods and consequent damages occur; falls of 5 or 6 ins. per diem being not uncommon. During the year 1908 the following falls took place on June 4th, 5th, and 6th respectively—4·10 in., 6·20 in., and 6·56 in., *i.e.*, 16·86 in. in three successive days, or an average of 5·62 in. per diem; the rainfall in each instance not being distributed over 24 hours, but falling during 3 or 4 hours of the day only. Again, on June 16th, 1908, a fall of 7·22 in. was registered; but the greatest daily rainfall recorded between the years 1902 and 1908 occurred on August 12th, 1903, when a fall of 8·22 in. was registered. The drainage of all the surrounding hills is carried down to the river, the watershed area being very considerable. During these heavy rains the river rises abnormally in the course of an hour or so, and falls again as rapidly; and when in flood, logs of timber, uprooted trees, etc., are carried down the stream, resulting in the almost certain destruction of any structure supported by timber piles. The Sinlumkaba Mill Bridge is so called because the military police had a mill house erected about 150 ft. on the up-stream side of the bridge, and by utilising the water power were able to grind their paddy rice, and other grain; but during the year 1907 the floods carried away the mill house, which in its turn carried away the timber bridge. The level of the crown of the arch in the present bridge has been placed 8 ft. above the highest known flood level, thus allowing sufficient space for floating timber to pass under the bridge without causing any serious damage.

GENERAL DESCRIPTION.

The bridge consists of one 40 ft. span, the rise of the arch being 12 ft., the outside width of the bridge 9 ft., and the width of the roadway inside parapets 6 ft. The haunches of the arch rise from a bed of lime concrete, as shown in Fig. 1. Jungle-timber staging was erected, and the centering cut to a template for the concrete to rest upon, timber side boards being provided to a little more than the full depth of the concrete. The upright posts of the staging were 8 in. in diameter, 3 ft. apart, buried to a depth of 3 ft. in the ground, and braced together with 6 in. by 3 in. timber cross-braces (see cross-section of centering, Fig. 4). The cross-girders were 8 in. by 8 in., longitudinal bracing timbers 8 in. by 4 in., and 6 in. by 3 in., with lagging and side boards 3 in. in thickness. Fig. 2 shows the arrangement and sizes of the timbers forming the staging. The staging itself rested upon wedge-shaped timber keys about 3 in. in thickness, three wedges being placed one above another to allow of the centering being lowered as required. On the arrival of the reinforcing bars at the bridge site they were bent to the required radius, a level piece of ground being cleared, the size of the arch laid out, and the bending process performed by native blacksmiths. The rods were then thoroughly cleaned by being rubbed smartly with sand, stones, etc., so as to free them of all rust and dirt. The reinforcing rods for the bottom layer were then placed in position over the timber lagging of the centering. All the rods were ½ in. thick, the longitudinal rods being spaced 9 in. apart, with cross-rods spaced 2 ft. apart at right angles to them, and both longitudinal and cross-rods were wired together at their intersections with 1-16 in. wire (see Fig. 5). This bottom layer of reinforcement was placed 1½ in. above the intrados of the arch (*i.e.*, above the lagging), and kept in this position by small chips of wood, temporarily nailed to the lagging. After the bottom layer had been fixed, the top layer of reinforcement was then placed in position 1½ in. below the extrados of the arch all the way, so that at the crown the two layers of reinforcement were 7 in. apart, whilst at haunches the distance apart was 3 ft. 6 in. (see Fig. 1). These bars were of the same dimensions as the bars of the bottom layer, placed at the same distances apart, and wired together in a similar way. This top layer of reinforcement was kept in position by timber cross-bars nailed to the timber side boards attached to the lagging, the reinforcement being suspended by these timber bars, and supported by pieces of timber 8½ in. in height at crown, and gradually increasing in length towards the haunches, fixed in an upright position from the lagging. As the concreting advanced, the pieces of timber used for keeping both reinforcements in position were removed. The radius of the extrados of the arch was 29 ft. 9 in., and the radius of intrados 27 ft. up to a point near the haunches, where a sharper curve of 5 ft. 6 in. radius was made, as shown in Fig. 1. The advisability of providing this sharper curve in the design can easily be seen, for by introducing it the springing of the arch was made to rise almost vertically, thus reducing the side thrust that would have come on to the haunches had the curve at the springing line been flatter. The whole of the arching was constructed of cement concrete, the thickness of the concrete at the haunches being 3 ft. 9 in., and at the crown 10 in. The following formula for ascertaining the thickness required at the crown in reinforced concrete arches is taken from a British engineering paper, and will be found useful :—

$$C = \frac{3\,S^2\,(R + 3\,F)}{4000\,R - S^2} + \frac{U\,S^2}{30000\,R} + \frac{L\,(S + 5\,R)}{150\,R} + 4$$

when C = Crown thickness in inches.
S = Span in feet.
R = Rise in feet.
F = Fill over crown in feet.
U = Uniform live load (lb. per square foot).
L = Live load concentrated on single track or roadway in tons of 2,000 lb.

As the moving load over the bridge would consist only of pack ponies, mules, or bullocks, an allowance of 100 lb. per square foot for the uniform live load, or 6 tons for the concentrated live load, would be ample, and by the above formula the thickness of crown for the Mill Bridge would work out at 6·8 in. Thus, the thickness provided, viz., 10 in., was really in excess of that theoretically required, but this being the first bridge of its kind to be constructed in Burma, and taking into consideration the possible inferiority of materials and workmanship, it was decided to take no risks, and to err, if at all, on the side of safety.

It is not the intention of the author to enlarge upon the subject of the design of the bridge, his intention being to refer only to the actual constructive work, as carried out, but before proceeding to give further particulars of the methods of erection it may be mentioned that the horizontal thrust for the whole bridge with a load of 100 lb. per square foot amounted to 14,060 lb. per foot of width, and for the half bridge similarly loaded the horizontal thrust was 12,328 lb. per foot of width. At the crown of the bridge the top of the arch was subject to tensile stress, and at A, B, A′, B′ (see Fig. 1) the tension was at the intrados of the arch.

FOUNDATIONS.

The formation of the foundations of the bridge did not present any unusual difficulty, the soil being of a hard gravelly nature, and suitable for bearing the necessary load. The foundations were carried down to a point about 4 ft. below the normal water level, and lime concrete was put in for this depth and for a width of 4 ft. (*i.e.*, extending 3 in. beyond the thickness of the arch at the springing line). Behind the arch foundations the depth of the concrete was reduced by steps to 3 ft. and 2 ft. for the foundations of the spandrel walls (see Fig. 1). The stone used was ordinary granite broken to pass through a ¾-in. ring. The sand was of good quality, and was found in abundant quantity along the river bed. It was screened through a 1-16 in. wire mesh before being used. The concrete for foundations was mixed in the proportion of 1 cubic foot of lime to 1 of sand, to 1 of surki (pounded brick), and the proportion of mortar to stone was 1 to 2, the stone being well washed before being mixed with mortar, and the lime slacked with water the evening previous to being used.

REINFORCED CONCRETE ARCH.

When both the bottom and top layers of reinforcing bars had been placed in position, and the lagging of the centering whitewashed in order to prevent the cement adhering to it, the work of constructing the concrete arch was begun. The stone was broken into two sizes, the larger size to pass through a 1-in. ring, and the smaller through a ½-in. ring. The larger stone was used at the haunches, where stone was subject to a greater compressive stress, and the smaller stone was used higher up the arch towards the crown. The bankers or platforms for mixing purposes consisted of mats spread on the ground, and the concrete was made in small quantities at a time, so as to ensure a thoroughly good mixture. This, in the author's opinion, is very important and worthy of notice by engineers engaged on concreting works in the East, where the mixing is usually done by hand labour, and where the essence of good concreting lies principally in the mixing. The mortar was first mixed together in the following proportion and quantity: 12 cubic feet of sand to 6 cubic feet of cement (the cement used on the work being supplied by an English manufacturer). This was well mixed together in a dry state, and while in this state 24 cubic feet of stone, which had previously been well washed, was added to the mixture and thoroughly incorporated. After the whole of the materials had been mixed dry, the mixing was continued while a small quantity of water was added through the rose of a watering can. As the platform of mats on which the mixing was done was about 50 ft. long by 20 ft. broad, three or four batches of concrete could be mixed simultaneously. The laying of the concrete was then begun, starting from both haunches at the same time, and working up towards the crown; but, previous to the laying of the concrete, all the reinforcing bars were grouted to a vertical height of about 2 ft. with a mixture of mortar, in the proportion of 2 parts of sand to 1 of cement, and when the concreting had reached this level the bars were grouted for a further 2 ft. upwards, and so on. The concrete, after laying, was rammed with wooden rammers having a face area about 6 in. in diameter, supplemented by others having a ramming surface about 1½ in. to 2 in. in diameter. the last-mentioned type of rammer being useful for compressing the concrete into corners and between the reinforcing bars. The concrete was put in almost dry, and very little ramming was done, but as soon as a basketful of cement concrete had been thrown in and had had a few taps with the rammer, the second basketful was thrown on top of it. The labourers employed for ramming while concreting was being carried out had, more or less, to sit or rest a portion of their body on the reinforcing bars, some of which were moved a few inches out of position, but care was taken that each bar should be placed in position again as the concreting reached its level. The cubical contents of the arch were 700 cubic feet, and with 50 labourers employed the actual work of concreting took 2½ days to complete.

Before the second and third day's work began, the surface of the concreting that had been completed on the previous day was roughened with a pickaxe, and a mixture of mortar applied to it, in the same proportion as that used for grouting the bars, so as to ensure a perfect joint. When the whole of the concreting had been completed, the arch was covered over with straw and sand, and watered for 10 days and the staging was struck on the 30th day. In striking the centering, one wedge was first removed throughout and then the second and third wedges were taken out in a similar manner.

It is usually the custom before striking the centering to build the spandrel walls and backing up to a certain height, but in this instance the centering was struck before any backing had been built. On striking the centering it was found that the cement had adhered to the lagging to a slight extent, and about an hour elapsed before the centering dropped from the arch. The author would therefore recommend two coats of whitewash, or, better still, a coating of grease, being laid on the lagging instead of one coat of whitewash, as was done in this instance.

The level of the crown of the arch was observed by the author before and after the centering was struck, and the sag was found to be practically nil, being less than 1-100th of a foot.

SUPERSTRUCTURE.

The backing of the arch was formed by parallel spandrel walls, made of coursed rubble masonry laid in lime mortar, having a thickness of 4 ft. at the base (nearly equal to one-third of the height of the walls), and with offsets of 6 in. at every 4 ft. in height, thus reducing to a width of 2 ft. at the level of the crown of the arch (*i.e.*, at a height of 12 ft.). At the crown level a masonry wall 18 in. in thickness ran right along either side of the arch for a height of 1 ft. (see Figs. 1 and 3), thus acting as a retaining wall for the filling in over the crown, and on this wall the parapet pillars of the bridge were built. The space between the spandrel walls was filled in with earth and boulders up to the road level. The parapet pillars of the bridge, which were also built of masonry, were connected by ⅞-in. square iron bars, built in at the ends so as to form a railing. The superstructure was delayed considerably in the months of June and July by the heavy rains. By a reference to the foregoing table of rainfall it will be seen that the rainfall during these two months was the heaviest recorded up to that time, and the effect of this exceptional rain was that for days together no work at all could be proceeded with, which accounts for the length of time taken to complete the erection of the bridge.

COST OF BRIDGE.

The cost of the bridge was more than was at first expected, or estimated for. This was due in the first instance to insufficient provision being made for the transport of materials, such as cement and iron, which had to be brought 26 miles either upon mules or elephants, the cost of thus conveying the materials being very considerable. Another expensive item was the centering, for the erection of which skilled workmen, such as carpenters and sawyers, had to be brought from long distances at a high rate of wages, and the process of cutting the centering to a template of the radius of the arch by labourers unaccustomed to this work was both tedious and costly.

The cement was brought up from Rangoon by rail and steamer as far as Bhamo, in casks, which were then opened, and the cement packed in tins containing about 0·6 cubic foot, and one mule load consisted of two such tins containing 1·2 cubic feet. The journey between Bhamo and Sinlumkaba occupied two days, and the return journey had to be paid for as well as the inward journey. The hire of a mule was 8 annas, or about 8d., per diem, so 1·2 cubic feet of cement cost 2 rupees, equal to about half a crown, for transport between Bhamo and Sinlumkaba alone.

The following tables give details of the cost of (i.) the reinforced arch, and (ii.) the complete bridge :—

(i.) REINFORCED ARCH.

Particulars.	Quantity.	Cost.					
Materials.		Rs.	an.	ps.	£	s.	d.
Cement	200 c. ft.	945	0	0	63	0	0
Sand	400 c.ft.	20	0	0	1	6	8
Stone for concrete, 1-in. and ½-in. gauge	800 c. ft.	160	0	0	10	13	4
Reinforcement	72 bars	130	0	0	8	13	4
Timber for centering	293 c. ft.	503	0	0	33	10	8
Labour.							
On erection of centering .	—	207	0	0	13	16	0
On cement concreting	—	125	0	0	8	6	8
On fixing and bending reinforcing rods	—	75	0	0	5	0	0
On plastering soffit of arch ..	—	22	0	0	1	9	4
	Totals Rs.	2,187	0	0	£145	16	0

Contents of arch = 700 cubic feet.

Therefore, cost per cubic foot $= \frac{2187}{700} =$ Rs. 3/1/11, say Rs. 3/2, or 4s. 2d.

(ii.) Reinforced Concrete Arch Complete.

Particulars.	Cost.					
	Rs.	an.	ps.	£	s.	d.
As shown in (i.) Reinforced arch .. .	2,187	0	0	145	16	0
Earth work in foundations	30	8	0	2	0	8
Lime concrete in foundations	370	0	0	24	13	4
Stone masonry in lime in superstructure ..	1,000	0	0	66	13	4
Cement pointing	44	4	0	2	18	8
W.I. parapet rails, including fixing	100	0	0	6	13	4
Cement plastering	3	8	0	0	4	8
Stone slabs for parapet tops	105	0	0	7	0	0
Totals Rs.	3,840	0	0	£256	0	0

Cost of bridge complete (40 ft. span) = Rs. 3840/- or £256/-

Cost of 1 lineal foot of span $= \frac{3840}{40} =$ Rs. 96/- or £6/8/-.

The cost of bridge, therefore, worked out as above for (i.) reinforced arch, Rs. 3/2, or 4s. 2d. per cubic foot, and (ii.) bridging complete, Rs. 96, or £6 8s. per lineal foot of span.

Of course, similar bridges will cost considerably less in localities where communications and conditions of labour are better.

Before concluding, the author would like to remark that the maximum live load that the bridge will ever be called upon to stand, *i.e.*, a loaded elephant, passed over the bridge on August 30th, 1908. After the elephant had walked over the bridge about six times the soffit of the arch was examined, and no cracks could be seen.

In conclusion, the author desires to thank Mr. Oliver, A.M.Inst.C.E., Superintending Engineer, Mandalay Circle, Public Works Department, who designed the bridge, for permission to submit this paper, and the attached drawings, for the consideration of this Society.

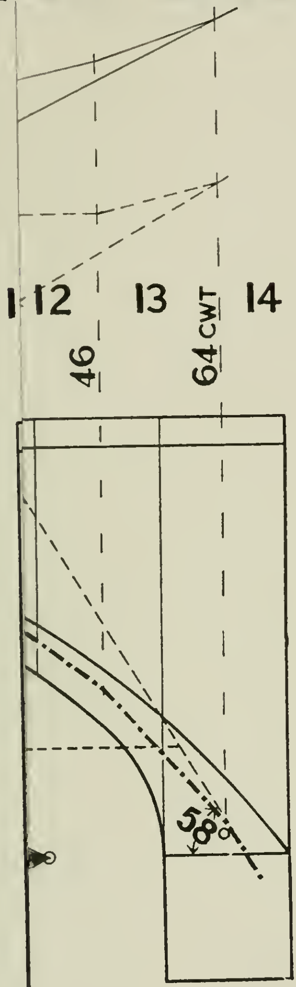
Discussion.

The President said it was unfortunate that the author of the paper was in India, and therefore unable to be present at its reading. But he was sure it was the wish of the meeting that its thanks should be conveyed to him for having brought the subject forward.

The bridge described in the paper was not a very large and important structure, yet the subject was one which it was well should be brought before the Society, particularly as a large proportion of the members were engaged in engineering work outside this country. The use of ferro-concrete for structures of this kind in countries where the conditions of transport were difficult was, he thought, a great advantage. When one bore in mind that the materials used in the construction of the Sinlumkaba bridge had all to be conveyed either by mules or by elephants, it was fairly obvious that if a girder bridge had been put up a considerably increased cost would have been incurred. However, by using reinforced concrete, materials could be taken up in detail. The cement was taken in parcels of a little over a hundredweight, and no doubt the steel bars were easily arranged in bundles, so that they would not weigh more than one or two hundredweights. By that method, materials could be delivered on the ground without involving any great expenditure. In view of the tremendous rainfalls, it was obvious that the streams must be very badly flooded ; and on inspecting the drawings the foundations shown appeared to be exceedingly light. The author stated that the soil on which those foundations were placed was of a hard gravelly character, and according to the drawing, the foundations were carried to a depth of only 2 ft. below the ordinary bed of the river. He should have thought that the foundations of a bridge built in such a position, subject to the scouring action of such terrific floods, might be undermined, and the stability of the structure thereby endangered. The position of the steel bars in the reinforcement of the concrete was a matter of very great importance, and the keeping of the bars in position was one of the great difficulties met with in reinforced work, particularly where labour was employed such as they had in this case, which was probably not too highly skilled or intelligent. Apparently the system adopted was to block the reinforcement up from the lagging of the centering by means of wooden blocks, and no doubt that was a good way of carrying out the work, provided that the wooden blocks were removed as the work was completed, otherwise they would be a source of weakness in the bridge. The author referred to " grouting " the bars, a term he did not understand. He supposed he meant the bars were given a wash of cement and water. The paper was well worthy of debate, and he hoped there would be a good discussion.

Mr. H. C. Werner said the paper was a very instructive one, especially in the latter part, dealing with the practical execution of armoured concrete work in countries such as India, where work was done under very difficult conditions. He disagreed from the statement that " the springing of the arch was made to rise almost vertically, *thus reducing the side thrust* that would have come on to the haunches had the curve at the springing line been flatter." He regarded that as an error, for the side thrust of an arch was determined by the main radii of the intrados and extrados (being 27 ft. and 29 ft. 9 in. respectively in this case), and it was not at all influenced by the introduction of a sharp curve near the haunches. The formula used for ascertaining the thickness of the arch at the crown was unknown to him. It was perhaps useful, but he had not yet had time to examine it thoroughly. As a rule, the best way of ascertaining the dimensions of the concrete and the reinforcement was by graphical calculation. By that, the greatest deviation of the polygon of stresses from the centre line of the arch was shown, and from that it was easy to calculate the tensile stresses produced in the arch by unequal loads. The timbering of the arch was very well designed and economical, especially as timber was very expensive over there. The concrete was also of proper nature, and the stone the proper size, namely, $\frac{3}{4}$ in. The armouring was ample, and corresponded to an arch which he himself constructed for the Great Eastern Railway near Tottenham, of 35 ft. span and 8 ft. 6 in. rise, armoured with $\frac{1}{2}$ in. longitudinal rods at 6 in. pitch and $\frac{3}{8}$ in. cross rods at 4 in. pitch, the arch being designed to carry steam rollers of 16 tons. He joined in the regret which had been expressed at the absence of the author, as it would have been very interesting to hear from him about the difficulties experienced in erecting armoured concrete bridges and other structures in India and such climates, and under circumstances which differed so greatly from those in this country, especially in the matter of temperature. There were great changes in temperature, and alternating dry and wet weather. There was also a difficulty in obtaining skilled labour. The data as to cost were very instructive, especially with regard to the timbering. Timber was a very expensive material in this country, but it was much more expensive in Burma, and, indeed, was almost prohibitive, working out to something like 2s. 6d. per square foot of intrados, whereas in this country it was nearer 2s. 6d. per square yard. And that led up to a question which had been much discussed, but not yet properly solved, namely, that of finding a way of constructing such armoured concrete work so that costly timbering could be avoided ; in other words, to arrange the armouring in such a way that it could carry the staging underneath without requiring special supports. It was well worth while for any engineer to attempt to solve that important question, on account of the costliness of timber in many countries. Also with regard to cement, the figures given showed that a ton of cement delivered in Burma cost about £8, or four to six times as much as in England. Those two expensive items made it difficult to reduce the cost of armoured concrete work there as much as in this country. Steel

THEETE BRIDGE



THE SINLUMKABA (BURMA) FERRO-CONCRETE BRIDGE

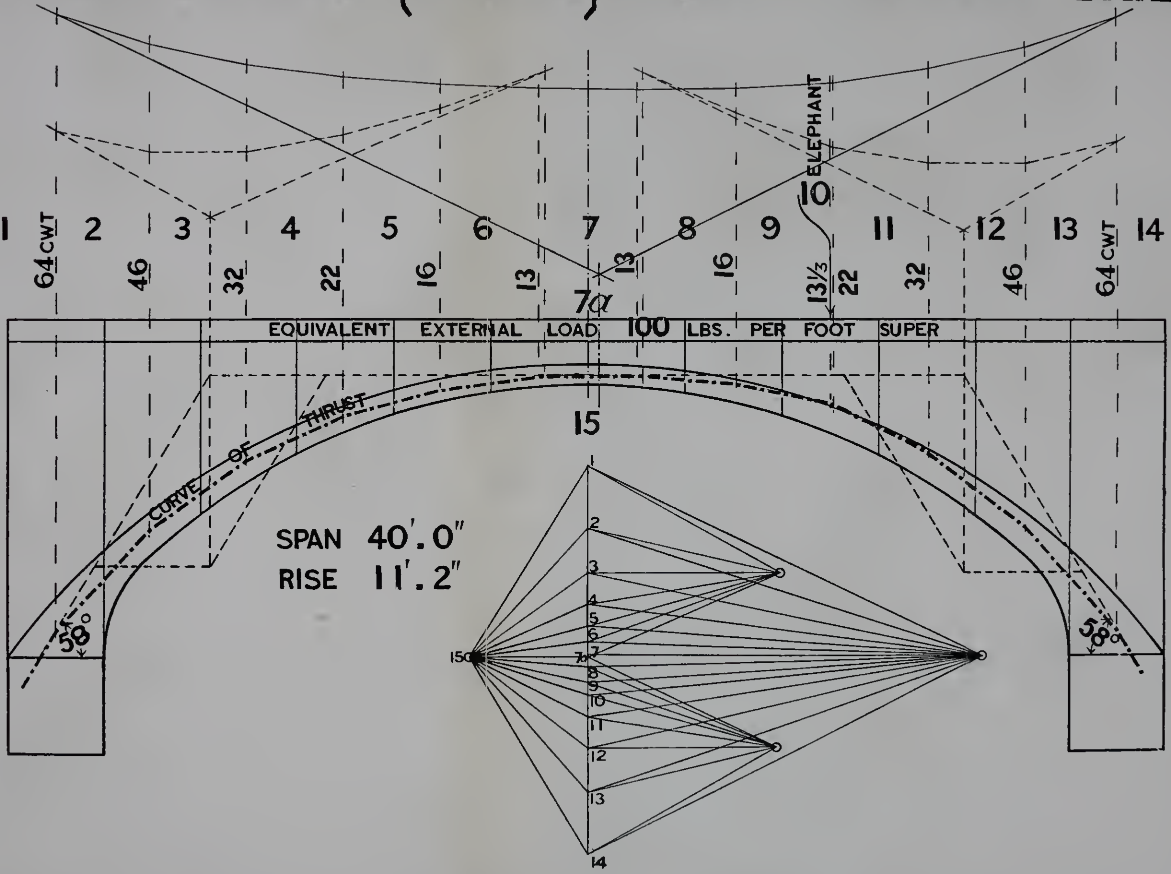


DIAGRAM ILLUSTRATING PROF. ADAMS' REMARKS.

structures in a climate where there was such heat and so heavy a rainfall, were very liable to corrode; hence ferro-concrete seemed to have a great future. The great value of the paper consisted in setting forth the difficulties encountered in such work in tropical countries.

Professor Henry Adams said that although the bridge which had been described was a small one, its details were instructive. The point to which he had intended calling special attention had already been referred to by a previous speaker, but he had prepared a diagram which might make it clearer. There seemed to him to be a grave misapprehension in the statement that the curve of the arch, by being sharply turned, altered the line of thrust. As a fact, the curve of thrust was practically independent of the shape given to that part. It reminded him of a common mistake made by architects who thought that a semi-circular arch had no thrust because the skew-back was horizontal. Whatever the thrust might be at the crown, there was the same horizontal thrust at the springing, and no change in the shape of the arch could alter that thrust, with the same span and rise. Allowance had been made for the external load on the bridge and for the elephant on the bridge in placing the line of thrust, and it was the extra weight of the elephant which drew up the line of thrust at that point. The line of thrust coming out at the springing of the bridge showed what was the theoretical outline of the arch, while the angle of skew-back or termination of the arch at the springing line should be at right angles to the curve of thrust, or about 30° with the horizontal, and that seemed to be a weak point in the design. The line of thrust kept fairly well within the thickness, so that there was no objection to be taken to the general shape of the arch, but he thought there was considerable error in the connection of the arch with the foundations. The President thought there was reason to fear the foundations being carried away by the floods, but he (Professor Adams) thought the foundations were safer than the superstructure, and that the bridge as a whole might be carried away off the top. Lime concrete was mentioned as used for the foundations, but it certainly ought to have been cement concrete, and securely united with the bridge. There was, however, no connection provided between the two. There seemed also to be a serious omission in the reinforcement of the arch. There were two sets of reinforcing bars, one near the intrados, and one near the extrados, but no connection between them. The lower reinforcing rods would tend to be pulled straight at the haunches, which meant that they would leave the bridge and come down below, where there was only 1½ in. of concrete to stop them coming through. It was the tying across from the inside to the outside which usually prevented that, but as in this case the bridge was only stressed in the centre to 115 lb. per square inch, and the reinforced concrete was capable of bearing 500 lb., there was a great margin of safety in the thickness ; otherwise he feared that the errors in design would lead to serious results. With regard to the erection, the author seemed to have taken very great care to ensure the concrete being properly mixed, the bars properly protected with cement-wash, and the whole work carried out as efficiently as the design permitted.

Mr. A. B. Geen said he disagreed from Prof. Adams' remarks as to the necessity of tying together the two systems of reinforcement. In a reinforced concrete beam, for example, the compressive stress and the tensile stress were only produced through the medium of the web of the beam, and the concrete in between the compressive flange was entirely abundant to transfer that stress, and although the tying together did actually increase the resistance to shear, he did not think it was absolutely essential until ultimate conditions were reached. Reference had been made to the somewhat peculiar design of the foundations, in which he assumed that there was no connection between the reinforced concrete arch proper and the line of concrete foundation. Having gone so far as to make any attempt at a reinforced concrete arch at all, it was a great pity the designers did not go further and make a rational one, by which he implied that the arch and foundation should have been monolithic. There would then have been no question as to the strength of the foundations. As they were at present, he would say they were very defective. It was obvious that the shaping of the arch near the springing had no effect whatever in decreasing the horizontal thrust. It was a fallacious idea, and unfortunately a very common one. One point of very great interest had occurred to him, namely, that there was a very great amount of concrete in the arch, especially near the springing, where the thickness was 3ft. 9ins. It seemed to him that, in view of the enormous cost of transportation, it would have been an easy matter to reduce the quantity of concrete very appreciably, simply by the insertion of a little extra steel, and he believed that steel was easily transported, as, it would probably be put into convenient lengths and bundles for transport. By decreasing the amount of concrete and increasing the amount of steel slightly the same strength could be provided, and, he believed, with great economy in transport. Had the foundations been joined to the bridge proper, Prof. Adams's diagram would have been inapplicable. There was nothing whatever to confine the line of thrust to the section of the concrete at all ; it might pass entirely outside it, and he thought the bridge could have been greatly improved. Another very interesting point in the paper was, that the author drew great attention to the necessity for mixing small quantities of cement. He himself had had some connection with reinforced concrete work in India, and he found that the question of mixing small quantities was a very important one. The action of cement was very rapid, and the evaporation of the water from it was also rapid. But even that was not more important than the ramming. He had been much struck by the figures giving the quantity of cement and sand used, as compared with the amount of the resultant concrete. It was an unusual proportion. He believed that had that ramming been done more thoroughly—granted that it was somewhat difficult—it would have been well worth the money. Possibly the liability to corrosion of the steel had largely been present in the mind of the designer, in that he had taken the trouble to grout the steel. He considered that it was lucky that this was done, for if the concrete were not well rammed, and if it were made under bad conditions, there would have been danger from this source. Work of that nature required the utmost care in that respect, as it determined to a great extent the ultimate compressive strength of the concrete. With regard to deflection, the author said "The level of the crown of the arch was observed before and after the centering was struck." Had the author been present he (the speaker) would have asked if the level of the under side of the centering was observed just before the centering was struck, and then afterwards ; or whether the level of the centering was observed when it was erected, the level of the under side of the concrete deduced therefrom, and the under side of the concrete measured when the centering was removed, because it seemed that the deflection of the bridge under its own weight was phenomenal. A good deal might perhaps be explained by the fact that the deflection of the centering was appreciable. He hoped it was so. He would also have liked to know what were the lengths of the bars used, and what care was taken to ensure that the junction of the bars was an efficient one. With regard to the lateral stiffness of the bridge, in view of the heavy floods, the bridge was very narrow, and he supposed the stone was obtained easily and cheaply. It seemed to him that the spandril walls were very heavy, and it might have been advisable to make those of reinforced concrete also. He could scarcely conceive of a more fortunate arrangement than to have such a very narrow bridge, which would render the centering for these vertical walls very easy, in that they could be tied across, and done rapidly and well ; and they would have added enormously to the lateral stiffness of the bridge. But even with a small portion of the wall all the way round, with such an efficient web as the arch ring itself would have formed, it would have been converted into a girder of tremendous strength, and would, he thought, have improved the conditions very much in the event of a flood.

Mr. D. A. Symons said that Professor Adams had already mentioned the points he had intended to speak on, which were chiefly in regard to the formula given in the paper. In this formula there was no reference to dead load ; it might have been embodied in that part of the formula under L ; "Live load concentrated on single track or roadway in tons of 2,000 lb." in which case it should have been mentioned. It appeared a great pity,in a paper of this description, that the stresses were not shown graphically. He agreed with other speakers, that provided the dead load and the distance between the springing and the crown did not vary, the horizontal thrust remained the same whatever the shape of the arch. He did not know whether Professor Adams had calculated what this thrust was, but in the paper it appeared to be 14,060 lbs. per square foot. He had calculated it by moments, viz. by taking the moment about the springing, and dividing by the rise of the arch. The result gave a less stress per square foot than that stated by the author. If there had been a diagram showing where the equilibrium line came in relation to the neutral axis of the arch they would have seen what part of the arch was in tension and also in compression. Reference had been made to whitewashing the centering in order to prevent adhesion when striking the centering. His experience was that soft soap was one of the best materials to use when dealing with shutters and concrete, If the author had used this material he would doubtless have had no difficulty with the adhesion referred to.

Mr. D. B. Butler said that previous speakers had dealt largely with design, and he therefore proposed to say a word or two about the materials used. In the first place, the foundations were described as composed of lime concrete, but he thought that description was more or less misleading as the term is understood here, since later on the author described how that lime concrete was made. It was not ordinary lime concrete but was made very hydraulic and much stronger than usual by composing it of one cubic foot of lime, one of sand, and one of pounded brick. It was well known that by adding pounded brick or ground burnt ballast to lime, it was rendered hydraulic, and therefore very much stronger, especially for positions like that described, which was obviously a wet situation. With regard to whitewashing to prevent sticking, he supposed it was done because lime was a local material and very cheap, whereas soft soap or similar imported material would have cost a good deal to carry up the country. The author rightly laid very great stress on the necessity of thoroughly mixing the concrete.

The author said: "Previous to the laying of the concrete, all the reinforcing bars were grouted to a vertical height of about 2 feet with a mixture of mortar, in the proportion of two parts of sand to one of cement." But how could he grout to a height of two feet? Unless he meant that he grouted the bars up to 2 feet from the lowest level previously reached in concreting. That was the only explanation that occurred to him. Another point was as to how the concrete was worked. The author said that he put it in almost dry. In a hot climate that seemed a most dangerous expedient, because it was well known that the higher the temperature of the surrounding atmosphere the quicker the cement would set, and unless an extremely slow-setting cement was used, he ran great risk of killing the set. He also said that very little ramming was done. By the combination of very dry concrete and very little ramming the author seemed to be courting failure ; the concrete would be as porous as a sponge and very much weakened, unless by thorough ramming the water were brought to the surface and the mass properly solidified. He congratulated the author on the precautions he took before he struck the centering, namely, covering the work with straw and sand and watering it for ten days. That was an admirable precaution in a hot climate, preventing the possibility of the water necessary for proper setting being evaporated before the hardening process could be properly completed. Other speakers had referred to the cost of the cement. He supposed it would cost about 45s. a ton at Rangoon, allowing £1 a ton for freight, and then one apparently had to allow anything between 60s. and 70s. per ton for transport up country, this working out at about £6 per ton altogether, or more than four times its value in this country. Obviously therefore the author was more than justified in taking every precaution to obtain the very best results from such an expensive material.

Mr. F. G. Bloyd said that the weight (100 lbs. per square foot) given by the author as the uniform moving load would be regarded as very light in this country, even for people. Professor Adams said he had taken into account the weight of an elephant, and he, the speaker, would like to know what that weight was.

Prof. Adams said he took it as 13⅓ cwt. per foot run of the bridge.

Mr. Bloyd, continuing, remarked that from the figures given in the paper the cost of the bridge worked out at £6 8s. 0d. per lineal foot of span, in a bridge 6 feet wide, which meant about £1 per foot super. For that cost a good girder bridge could be put up in this country, but probably not in Burma. Taking into account the difficulties of construction, he did not think the cost was anything out of the way. In England they were starting to put up occupation bridges with a load of 3 cwt. per super. foot over floor area, and the cost of such bridges was 15s. 9d. per square foot complete. The cost of materials was lower in this country than in Burma and he therefore thought those responsible for the construction of the bridge were to be congratulated on putting up a comparatively cheap structure. He would like to know whether any restriction was put on the loads, or whether any load which happened to come into the district was allowed to pass over the bridge.

Mr. H. Conradi said that in a paper on the reinforced concrete used in waterworks construction in America, read before the Society in May, 1907, ferro-concrete was specially recommended for the construction of reservoirs, dams, sewers, and other works ; and in a paper read at the Royal Society of Arts in March, 1908, its application was further recommended for use in engineering and architectural works, such as bridge construction, tunnels, retaining walls, jetties, quays, stations, sheds, roofs, factory chimneys, and even for railway sleepers. He (the speaker) could not understand how engineers could recommend a combination of two such widely different materials for structures required to resist strains or stresses, especially for bridges and girders. One material was composed of elastic and flexible fibres, able to stand elongation, compression and shearing, while the other was an agglomeration of molecules with but slight cohesion, and with no adhesion to iron or steel. Only in compression would there be some adhesion. From his experience in bridge and girder work, he felt convinced that any strains would cause the molecules of concrete to slide gradually along the fibres of the iron and steel. If the concrete was not strong enough to resist the strains by itself, internal cracks would probably occur, similar to the fine internal flaws developed in steel under the steam-hammer, due to some of the fibres not being in an intimate state of cohesion, and the concrete would gradually break away. But if the concrete was strong enough by itself, it would prevent the iron or steel bars doing their work, each of the materials working in its own way, uninfluenced by the other.

Mr. Henry C. Adams said there were one or two points in the paper which were not clear to him, and which he mentioned as he presumed the author would communicate his reply on the discussion. The formula used was new to him (Mr. Adams) and he wished to enquire in what publication and on what date it appeared ; wherever it was, there might be some further explanations as to how it was arrived at. With regard to the stone for the concrete, he would like to know what the actual size of it was, as in one part of the paper it was said to have been broken to pass a $\frac{3}{4}$ inch ring, and in the table of the estimates it was given as being 1 inch and $\frac{1}{2}$ inch gauge. In the quantities for the arch there were 800 cubic feet of stone included for the concrete, in addition to 600 cubic feet of cement and sand, but when they were put together it only made 700 cubic feet in the arch. He would have thought that the arch measurement was at least equal to the stone measurement, if not more. The author had stated that when the centering was struck, the cement adhered to the lagging, and it required an hour for it to drop. It would be interesting to know whether any concrete came away with the centering, and if so, to what extent.

The resolution of thanks to the author was carried by acclamation.

The President announced that the next Ordinary Meeting (October 4th, 1909) and subsequent meetings would be held at Room 18, Caxton Hall, Westminster, instead of The Royal United Service Institution as formerly.

It was also announced that the Council had elected Mr. Maurice Fitzmaurice, C.M.G., M.Inst.C.E., Chief Engineer to the London County Council, as an Honorary Member of the Society to fill the vacancy caused by the death of Dr. Francis Elgar, F.R.S.

The proceedings then terminated.

Mr. P. G. Scott wrote congratulating Mr. Haldwell for placing on record the methods of construction of reinforced concrete work in Burma, as well as on the clearness of the explanatory drawings. Although the insufficiency of statistics regarding rainfall was deprecated by the author it would not affect the design of the bridge, as nothing could be more reliable than knowing the highest flood level of the river to be spanned, and calculating the discharge by the Mississippi or other suitable formula. It was not stated whether the reinforcing " bars " or " rods " were square or round, but presumably they were ½ inch diameter steel rods. The proportions given for lime concrete were those generally adopted all over India, with slight modification, to suit the kind of ballast and sand used, but it was usual to use a broad shallow platform, floored with bricks or flagging, and not mats, on which to mix the concrete, as the mats would soon wear away. As regards the cement concrete, it would seem that if the ballast had been broken into sizes ranging from ½ inch to ¾ inch and mixed together, it would have proved more satisfactory. Mr. Haldwell had said very little about the qualities of the sand used ; clean, sharp sand free from earthy matter and not too fine was what was required for good concrete work. It was essential that all the interstices in the ballast should be filled with mortar, and that the sand used for mortar should be well surrounded with lime or cement ; this was highly important for reinforced concrete work where the steel had to be protected from corrosion. Experiments had also more or less decided the fact that neither the ballast nor the sand should be all of one size. The author stated that the concrete was put in almost dry. This was a mistake as regards reinforced concrete work, which could not be rammed to the same extent as ordinary concrete and should therefore be put in fairly wet so that there might be no voids, and the adhesion of the reinforcement to the concrete might be as great as possible in order to ensure a monolithic mass. From various tests made by engineers, it was known that the greater the adhesion of the reinforcement the stronger the mass of the reinforced concrete. It was instructive to compare the cost of the reinforced concrete arch with the rest of the work, and it would appear that another type of bridge (not timber) would have been more economical, but the Burma Public Works Department were fairly alive to the importance of reinforced concrete work. He (Mr. Scott) had had to draw up specifications for certain reinforced concrete works when officiating executive engineer of the Irrawaddy Division and had had to design a bridge for the Commissioner of the Irrawaddy Division. This bridge had to carry cart traffic and the flooring was of concrete reinforced with expanded metal carried on rolled steel joists. It seemed rather doubtful whether the bridge erected by the author was the first reinforced concrete bridge to be erected in Burma, as he (Mr. Scott) had been called upon to report on a reinforced concrete cart bridge under construction in the Bassein Division as early as May, 1908, but as the engineer-in-charge was called away, he (Mr. Scott) had been unable to inspect the bridge.

As regards reinforced concrete work in general a fair amount has been done in Burma in the case of buildings, expanded metal being as a rule the reinforcement used.

Mr. W. E. Haldwell in communicating his reply to the discussion wrote that he quite agreed with the President as to the great importance in works of this nature of keeping the bars in position while concreting was in progress. The bars in this instance were retained in place by blocks of wood about 1½ inches by 1½ inches in size, which were loosely nailed to the lagging, care being taken to remove all blocks as the concrete was laid. The term "grouting" applied to the reinforcing bars meant coating with a wash of cement.

In reply to Mr. H. C. Werner, the author regretted the statement made that the vertical springing at the haunches tended to reduce the side-thrust, which of course was an error, as the thrust was determined by the radii of the arch, and was irrespective of the sharper curve introduced near the haunches.

The point raised by Mr. Werner regarding the expensiveness of timber was certainly a serious drawback to the construction of reinforced concrete bridges in countries where the price of timber was prohibitive, and if a method could be discovered whereby the armouring could be arranged without requiring special supports, it would mean an immense saving in this class of work.

Professor Henry Adams had remarked that there was no connection between the arch and the foundations, and therefore the structure was liable to be carried away "off the top." This was rather an extreme view of the case, for the concrete face of the foundations had been picked up to a depth of a couple of inches before the arching work commenced, thus bonding the arching to the foundations, and forming a solid structure; the joint between the arch and foundations being practically as strong as any joint in the arch itself. The author would admit

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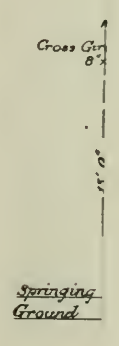

THE SINLUMKABA BRIDGE. By W. E. HALDWELL, B.A., M.S.E

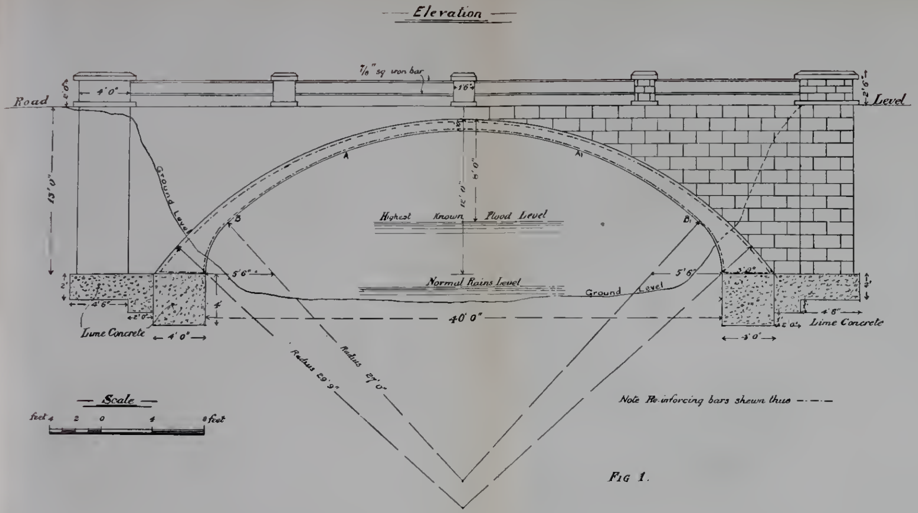

FIG 1.

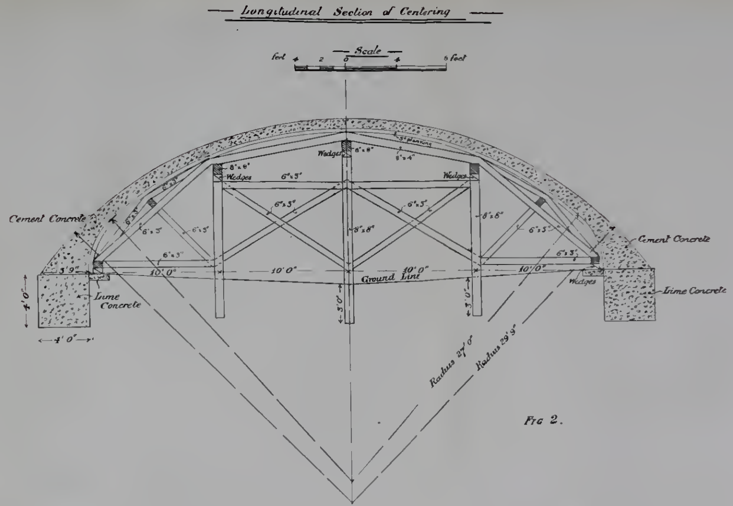

FIG 2.

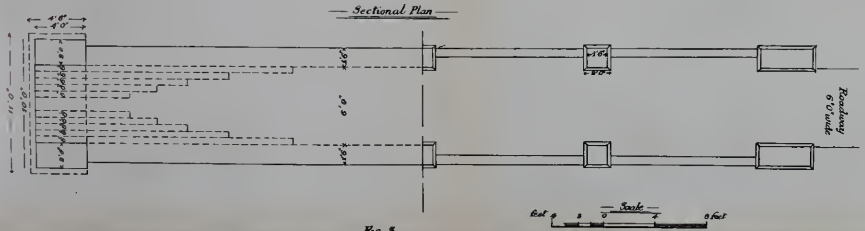

FIG. 3.

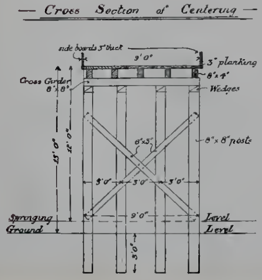

FIG 4

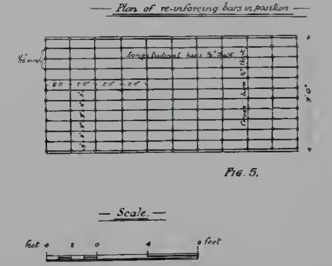

FIG. 5.

that had the reinforcement been imbedded in the foundations, this would have been a better arrangement.

He could not agree with Professor Adams in his statement that there was a serious omission in that the two rows of reinforcement were not connected, as this appeared to be rather an unnecessary precaution.

Mr. A. B. Geen enquired as to the manner of taking levels on the arch. The levels were taken before and after removal of the centering, and in both instances were taken on the top of the crown of arch, and not on the underside of the centering. The longitudinal bars were of the whole length of the curve, and there were therefore no joints. Mr. D. A. Symons had remarked that the formula for determining the thickness of the reinforced concrete arch at the crown did not refer to dead load. The dead load was, however, embodied under live load (L) which was shewn as concentrated on a single track or roadway in tons of 2,000 lb.

Whitewash was used on the centering, because it was easily procurable and cheap, whereas soft soap or other similar material would have been costly to import. The author believed that newspapers laid on the centering would have answered the purpose just as well. Mr. D. B. Butler had referred to the lime used in the foundations. This was composed of equal parts of lime, sand, and surki (*i.e.* broken brick) and was very hydraulic, and stronger than ordinary lime mixed without surki. He (Mr. Butler) also enquired how the reinforcing bars were grouted to a vertical height of 2 feet. By this was meant that just before the concreting of the arch commenced, all the bars were grouted with a mixture of cement and water for a height of about 2 feet from the springing. When the level of the concreting had reached to within 6 inches of this height, the bars were grouted for a further length of 2 feet, and so on until the arching was completed. Several members had remarked on the concrete having been put in practically dry, and on the little ramming that had been done, but the author believed that cement concrete could be ruined by over ramming, and that in a slow-setting cement, such as was used, a great deal of ramming was not only unnecessary but liable to prove disastrous. In this instance, the cement was put in practically dry, and even with the little ramming that was done; the water soon appeared on the surface. Before the bridge work was started, several tests of the cement were carried out. Two boxes 6 feet by 9 inches by 6 inches were filled with cement concrete, one containing concrete which had been put in fairly wet, and well rammed, and the other, concrete put in practically dry with little ramming. Both boxes were then covered over with straw, and watered for a week, when on breaking open the boxes the concrete in the first crumbled away immediately, whereas that in the second box, which had been put in dry and had had very little ramming, was hard set. The author would also point out that Sinlumkaba had not a hot climate, its elevation being 6,000 feet above sea level, and the maximum temperature seldom exceeding 70 ° Fahr. The author differed from Mr. F. G. Bloyd in his remark that the weights carried by the bridge were very light, even for people. The bridge was designed to carry a uniform moving load of 100 lb. per square foot. This worked out, in the Sinlumkaba bridge, to a concentrated live load of 12,000 lb. or 6 tons, at the centre. As the weight of a large elephant would only amount to about 6,000 lbs. and this would be the maximum load that the bridge will ever be called upon to carry, the author considered that ample allowance had been made. No restrictions were put on the loads, and any load that happened to come over the road was permitted to pass over the bridge. Since the paper had been written, a mountain battery of about 800 men, with their equipment of guns, baggage, etc., passed over the bridge without any damage being caused to the structure.

Mr. H. C. Adams enquired about the derivation of the formula applying to thickness of reinforced concrete arches. The formula had been published in "The Engineer" a few years back, and was, the author believed, generally used in designing similar structures in America. The author regretted to be unable to furnish the date of publication.

Regarding the size of stone used in the concrete, by referring to the sections headed "Foundations" and "Reinforced Concrete Arch," it would be seen that the $\frac{3}{4}$ inch stone was used in the foundations, whereas, the 1 inch and $\frac{1}{2}$ inch stones were used in the arch, the larger size at the haunches, and the smaller higher up towards the crown of arch. The quantity of stone, viz. 800 c. ft. plus 600 c. ft. of sand and cement, was the actual quantity used in the arch. A certain proportion of this was wasted in transit between the mixing platforms and the bridge, but this wastage was very small, care being taken to reduce it to a minimum. Thus the proportion of stone measured, to the arch measurement, was in the ratio of 100 to 87.5.

The lagging, when it dropped from the arch, in about one hour, came away clear, without any concrete adhering to it.

Replying to Mr. P. G. Scott, the reinforcing bars were round steel rods of $\frac{1}{2}$ inch diameter. The mats, for mixing concrete, were used for the sake of economy, and were, for the purpose required, just as efficient as brick-floored platforms.

VACATION VISITS.

During the Summer Vacation of 1909 four half-day visits to works took place, of which particulars follow.

Vickers, Sons & Maxim's Erith Works.

On Wednesday, May 12th, 1909, facilities were kindly granted for the Society to inspect the Erith works of Messrs. Vickers, Sons & Maxim, Ltd., which are principally used for the production of the smaller kinds of artillery. Four to five thousand men are employed when the works are in full swing.

The entire establishment, including the main factory, the North Kent Works, and the St. John's Works, covers an area of about 18 acres ; the greater part of the buildings having been erected since 1898, and the oldest portion dating back no further than 1888. For purposes of management the works, excluding the office section, are divided into 23 departments, each having a responsible head, who is accountable to the Superintendent, Mr. J. S. Conradi, for the work of his division.

The party first passed into the Gun Mechanism Department, where breech mechanisms are made for quick-firing guns, from 12in. to the smallest in use, and the guns are also brought to this department to be fitted for their reception. The Pom-Pom, which is really only a breech mechanism, is manufactured in this section, as are many designs of gun-sights.

Having walked through the Ammunition Department, which is fitted up for machining all kinds of shells, from 20-pounders to Pom-Poms, the Gun Turnery was visited, and here guns in various stages of machining were inspected. The machines in this department included a heavy Landis Grinder, which was effectively dealing with gun cradles, and a high-speed planer, both driven direct by electric motors.

The Gun Mounting and Carriage Department was then entered ; this department is entirely built of steel, and consists of three clear and two galleried bays. In the clear bays, three 20-ton and three 10-ton overhead electric cranes work. Heavy machines are arranged in the clear bays, so as to be served by the cranes, while the lighter ones are placed under, and the smaller machines upon the galleries.

Naval and Garrison gun mountings, from 6in. downwards, are completely machined and erected in this shop, besides all kinds of field carriage work. The complicated sights for large naval guns are also erected and tested here.

As practically the whole of the works are electrically driven, a large power station is in operation, and the Members wer shown the arrangements for distributing electrical energy to the various buildings and departments.

Having passed through the smithy, where forging machinery of various types and sizes is installed, for supplying the machine shops with forgings and stampings, the party entered the foundry, where metal castings are made ; a special pot-furnace for melting up headers, etc., being erected here.

The Members proceeded through the tool and gauge shops, and were then conducted to the St. John's Works, where two shops have been recently erected. One is the Maxim Gun Factory and the other the Wood-working Department. The Maxim Gun Factory covers an area of 69,000 square feet, or about 1½ acres, and consists of ten bays, each 25ft. wide and about 300ft. long. Here Maxim guns are made to suit every kind of modern rifle bullet, and an instructive explanation of the automatic mechanism was given by one of the staff. The milling machine for producing the many complex forms found in Maxim gun and rifle work is very much in evidence. A large number of Peddie rifle sights were being put through at the time of the visit.

After the round of the shops had been made, tea and light refreshments were kindly provided by the firm for their visitors, after which the President, in a brief speech, referring to the enjoyable and instructive afternoon they had spent, proposed a vote of thanks to the management, which was carried by acclamation and suitably acknowledged. The total attendance was 57, including a number of members of the Civil and Mechanical Engineers' Society.

London Hydraulic Power Co.'s Power Station.

By the courtesy of Messrs. Ellington and Woodall, MM.Inst. C.E., engineers to the London Hydraulic Power Co., a visit was paid, on Wednesday, June 16th, 1909, to the company's new power station, which is in course of construction at Grosvenor Road, Westminster, about 300 yards west of Vauxhall Bridge.

When completed this building will be the largest of the company's pumping stations, and will replace the existing station at Millbank Street, which has been acquired by the L.C.C. for the Westminster Improvement. At the time of the visit the works were not in a sufficiently advanced state for the reception of the machinery, and interest centred principally in the ferro-concrete construction (Hennebique system).

Reservoir.—This is arranged in six compartments, each about 100ft. long, 38ft. wide, and 16ft. deep, the top water level being the level of the highest known tides. The vertical walls are all 12in. thick at the bottom, tapering to 8in. thick at the top, and spread out in the form of a T flange 3ft. wide, the flanges forming flat surfaces which are being utilised as gangways. The construction is so designed that the vertical walls are strong enough to resist the water pressure, when each or all the compartments are full, without external support of any kind.

ROADWAY.—The roadway is about 260ft. long, having an average width of 17ft., and is carried along its length between vertical walls 17ft. apart. Underneath are the pipe subways. The ferro-concrete beams and floor forming the roadway are designed to carry a moving load of 16 tons on two axles, in addition to a superload of 1 cwt. per square foot.

FILTER FLOOR.—This is carried by the walls of a building 89ft. long and 52ft. wide, having a central longitudinal beam supported by three columns, all the beams and columns being of ferro-concrete. The filter plant weighs 800 tons, which, with a superload of 150 lbs. per square foot, brings the total weight to be carried by this floor to 1,100 tons. The three ferro-concrete columns are 22in. square, and support other columns carrying the overhead water tank, the total load on each column being 310 tons.

The COAL STORE FLOOR is designed to carry a load of 7 cwt. per square foot, and covers the same area as the filter floor ; the central portion is carried on the ground, and at each side the floor spans the coal conveyor trenches through which coal is carried to the boilers.

The BOILER BLOW-OFF TANK is a covered tank about 8ft. deep. The length is 36ft., and the width varies from 12ft. 6in. at one end to 5ft. at the other end.

The DRAINS TANK is a small covered tank 9ft. long by 6ft. wide by 4ft. 6in. deep

These two tanks are below the level of the general drainage, and hydraulic ejectors will be used for pumping the water into the drains.

The buildings when completed will comprise engine and boiler houses, accumulator tower, chimney shaft, coal store, filter house, workshop, store room, men's room, and foreman's house, with water tanks over the boiler house and filter house. The settling reservoirs in the rear cover an area of 2,550 square yards, with a total capacity of about 2¼ million gallons. The wharf on which the coal-handling apparatus, etc., will be erected, has a river frontage of 100ft., subways under Grosvenor Road connecting the two sites. The station is designed to supply 200,000 gallons of power water per hour, at a pressure of 800 lbs. per square inch. River water is to be conducted into the settling reservoirs at the rear through two lines of 20in. pipes, laid at about half-tide level. The reservoirs can be emptied to the river at low tide through 14in. drains. The water after settling is to be pumped from these reservoirs through the condensers into an overhead tank above the filter floor, is then filtered, and from the filters will flow into another tank at a lower level, over the boiler house, from whence it will be conducted to the main engines with a gravity head, and pumped into the power mains.

There are at present about 165 miles of hydraulic power mains laid in London, and served by five central stations from two to three miles apart. The supply is over 20,000,000 gallons per week, with about 6,000 machines at work.

GREENWICH POWER STATION (L.C.C. TRAMWAYS).

The third vacation visit of this Session took place on Wednesday, July 14th, 1909, when, by the courtesy of Mr. A. L. C. Fell, M.I.E.E., M.I.M.E., Chief Officer of the L.C.C. Tramways Department, and of Mr. J. H. Rider, M.I.E.E., Electrical Engineer, facilities were given to inspect the Greenwich Generating Station, which is situated on the south bank of the Thames, and occupies a site about 3¾ acres in extent with a river frontage of 240ft. Mr. Rider conducted the party, and pointed out the chief matters of interest; a cordial vote of thanks being accorded to him at the close of the visit.

BUILDINGS.—The buildings consist of a boiler house and engine room, each 445ft. long by 80ft. wide, and auxiliary buildings adjoining. The foundation is a concrete raft 6ft. thick extending over the whole site, with concrete retaining walls, and the superstructure consists of a steel framework, having an external casing of brickwork with Portland stone dressings.

CHIMNEYS.—There are four chimney shafts, two 180ft. high and two 250ft. high above the firing floor, each chimney having an internal diameter of 14ft.

PIER.—A large pier, T-shaped on plan, projects 118ft. beyond the river wall and has a river frontage of 200ft., the width being 40ft. 6in. Three electric jib cranes unload coal from the steamers into trucks, and the latter pass over weigh-bridges before discharging into the outside coal bunker of 2,000 tons capacity. From the outside bunker two lines of coal conveyors, each of 40 tons per hour capacity, carry coal to the main bunkers (each holding 200 tons) placed over the boilers. In returning, the conveyors pass under the boilers and carry the ashes to a storage hopper under the pier.

BOILERS.—The boiler house contains 24 Stirling boilers, each evaporating 16,300 lbs. of water per hour, and 24 Babcock and Wilcox boilers, each evaporating 18,200 lbs. of water per hour. All the boilers are fitted with chain-grate stokers and self-contained superheaters, and the working pressure is 180 lbs. per square inch. CO_2 recorders can be connected to any boiler. The usual working draught is equal to about ¾in. of water at full load to ½in. at half load.

ECONOMISERS.—Each pair of boilers has an economiser of 360 tubes. The temperature of the chimney gases is 280 deg. to 300 deg. Fahr., and of the feed water 230 deg. to 250 deg. Fahr.

BOILER FEED.—The boiler feed is effected by twelve horizontal 3-ram pumps driven by direct current motors through worm gearing. Each will deliver 8,000 to 9,000 gallons per hour, the suction and delivery pipes being in duplicate. Two voltages of supply give two speeds to the motors. Make-up water is obtained from an artesian well 8½in. bore and 350ft. deep, and is treated in a Harris-Anderson water softener.

PIPEWORK.—The steam pipes are of lap-welded steel, arranged with a fall to the engine separators, giving natural drainage.

GENERATING PLANT.—This consists of four vertical-horizontal reciprocating sets,each of 3,500 k.w. capacity, running at 94 r.p.m. and four turbines (two of the reaction type and two of the impulse type) each of 5,000 k.w. capacity, running at 750 r.p.m. Separate surface condensers are provided to each set, the circulating water being drawn from the Thames.

SWITCHGEAR.—Of electrically operated remote control type. The main bus-bars can be divided into two portions. There are 8 sets of sectional bus-bars, to each of which four sub-station feeders are connected. The 8 generators can be run all in parallel and in two groups of four, or each independently on its own four feeders, or any set or sets may be run separately and the remainder in parallel.

The normal capacity of the station is 34,000 kilowatts, the overload capacity 42,500 kilowatts, and the working capacity 30,000 kilowatts (allowing for spares).

MESSRS. HILL'S ORGAN BUILDING WORKS.

The fourth visit of the Session took place on Wednesday, September 22nd, 1909, to Messrs. Wm. Hill & Son's organ building works, at Camden Road, Islington, N., where the party (including a number of ladies) had the opportunity of inspecting the processes by which large organs are built up.

The house of Wm. Hill & Son is remarkable as being the oldest firm of organ builders in this country, being descended from the celebrated artist, John Snetzler, whose business, founded in 1755, passed into the possession of Thomas Eliot, and then to his son-in-law, William Hill, the distinguished organ builder, in the earlier part of the nineteenth century. For nearly a hundred years, therefore, the business has been in the Hill family, and is now directed by the grandson of the William Hill aforesaid.

Many of the principal organs in the United Kingdom and the Colonies have been built by the Hills, including some of the most celebrated instruments in the cathedral and parish churches of the country, besides those in secular buildings.

The present works in York Road, built in 1873, were constructed to suit the requirements of the trade. They consist of offices, a large hall, 80ft. by 40ft. (in which the organs are erected after the different parts have been prepared), and an engineering shop, where, in addition to the ordinary work connected with organ building, the firm make their own hydraulic engines for organ blowing. Among a number of other departments are shops for metal casting, manufacturing, and voicing the various pipes, shops for the joiners, casemakers, sound-board makers, and bellows makers, and for making and putting together the action work.

Outside the workshops is an extensive timber yard, where a large stock of hard and soft woods is stacked and kept to mature.

The machinery connected with the works is driven by a 30-h.p. gas engine, whilst a steam boiler is used to generate steam for heating and other purposes.

October 4th, 1909.

EDWARD JOHN SILCOCK, PRESIDENT

IN THE CHAIR.

THE STATUS OF THE ENGINEERING PROFESSION.*

By G. ALLAN THOMAS, A.M.I.M.E.

It is obvious to the most casual observer that, although the Science of Engineering enters very largely into our modern civilisation, yet the position of engineers at the present day is very far from being satisfactory, and, on account of the conflicting influences at work, is not likely to improve until some definite steps are taken to secure for them that recognition which is accorded to members of other professions.

Here we have a body of men who, by reason of their education and scientific attainments, are quite worthy to be ranked with any doctor or lawyer in the land, but who are too often confounded by the general public with the men who mend our frozen pipes, or put together the parts of a bicycle ; the latter being of undoubted utility in their proper sphere, yet having no claim to be described as engineers. The medical practitioner would rightly object to being placed on a par with the dispenser, or the artist with the sign painter, but engineers at the present time seem to be content that their profession should have no definite standing.

Presumably it has not seemed to matter in the past, nor perhaps did it matter when our numbers were less, but now the interests of our profession from every point of view—material and otherwise—demand for it some measure of popular recognition.

Members of every branch of the profession, civil, mechanical, or electrical, are equally concerned, whether they are actively employed in carrying out engineering works as consulting engineers and superintendents, or engaged in research work, and the like. It is lack of unity from which engineering is suffering at the present day. At one time engineering was principally concerned with road making, bridge building, and the opening up of various waterways throughout the country for the conveyance of passengers and goods, and it was then a simple matter to provide for the interests of the men engaged in such work. Early in the 19th century a society was formed for this purpose, and proved to be only the forerunner of several societies that arose in connection with the various branches of engineering as the work became more specialised. Unfortunately, each society has been so intent on developing the special branch with which it is most concerned that the needs of the profession as a whole appear to have been lost sight of, and this lack of cohesion has been detrimental to the advance of the engineer in the public estimation.

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* This paper has been adjudged the best of those submitted in competition for the Status Prize for 1909, which has therefore been awarded to the author.

It is high time, therefore, that all those who realise the present state of affairs should endeavour to find some means whereby the various bodies may be united under one central authority, for the enhancement of the dignity of the profession, and the correction of those evils which are the result of too independent action on the part of the younger branches.

Stated briefly, the following are the main difficulties with which the profession has to contend at the present time:—Overcrowding; misuse of the term engineer; multiplication of societies; what may be called the advertising problem; and, finally, with regard to consulting engineers, the question of fees, and the mal-practice of some manufacturing firms in giving free advice to clients.

OVERCROWDING.—This objection might be brought almost equally well against any of the professions, but engineering perhaps suffers more than others from the constant influx of men lacking sufficient scientific training, having no great love for their work, but apparently tempted by the ease with which a footing may be gained as compared with other professions. The author hopes that he may not be misunderstood in attributing this fact to the undue value set upon technical school training. If engineering as a profession is to vie with others, any education in preparation for it must be on the same lines as obtain elsewhere.

Technical schools, although they perform excellent work, cannot give their pupils that solid foundation which is so necessary before work of a special character can be entered upon, nor can they in the nature of things inspire their students with that *amour propre* which is essential to maintain the dignity of the profession. Let technical schools confine their efforts to training mechanics in theoretical work, and encouraging them to think for themselves. Then, if a pupil shows a distinct engineering bent, let him be encouraged in every possible way by scholarships and subsidiary grants to continue his education at a recognised centre, where he may qualify for the profession.

It is not the author's wish that the qualification for admission to the engineering profession should be a social one; candidates from every rank of society must be welcomed, but they must show proof of natural talents above the average. Up to the present there has been too much encouragement of mediocrity, tending to lower the general standard.

MISUSE OF THE WORD ENGINEER.—The title of engineer is to be seen tacked on to almost every imaginable industry, and can be freely adopted by anyone who cares to do so. It ought to be possible to restrain persons from misleading the public,—whether intentionally or otherwise—in this way, so that the term engineer would convey but one idea to the public mind. Unfortunately, the evil has gone on for so long that it will be difficult to find a remedy. In the case of the medical profession, the old term apothecary was discarded, and conveniently forgotten, a new title having been adopted and universally recognised, except in University towns; but in the latter case the use of the ancient distinction is restricted to those who are entitled to it. Perhaps it would be possible to find a new name by which to designate professional engineers, or to devise means for preventing the misuse of the old title.

MULTIPLICATION OF SOCIETIES.—Specialisation has reached such a point that the tendency of the present day is all towards an increase in the number of engineering societies. When used for the purpose which they are intended to fulfil, viz., for encouraging the inter-change of ideas on specialised technical subjects and attracting men who are not yet qualified—apart from the special subject in which they are interested—to join the older institutions, such societies cannot be too highly commended; but for these societies to allow their members to adopt the initials of their titles as a distinguishing mark must result in cheapening the value of such distinctions and cause confusion in the minds of the public.

ADVERTISING.—Compared with other professions, the one that most nearly resembles our own is that of medicine, as it has but recently attained to its present high position, and in it a certain amount of mechanical skill is necessary in addition to high scientific attainments.

Medical men have recognised the advisability of differentiating strongly between profession and trade, and have, as far as possible, relegated the merely mechanical duties to an inferior body of men. To accentuate the distinction more strongly, they have made it an unwritten law that no professional man as such shall advertise himself in any way. The mechanical branch of engineering is brought into much closer contact with actual trading than any other, consequently it behoves those engaged in this class of work to be doubly careful. Engineers must remember that this matter, in common with other points referred to in this essay, must not be regarded solely from their own view-point, but also from that of the general public, and considerations which they themselves could afford to neglect must for this reason receive careful attention. In these days of keen competition, it is very evident that engineering businesses, in common with others, cannot afford to abstain from advertising. At the same time to allow managers of these concerns to use their position as members of the engineering profession for the purpose of personal advertisement, and yet to veto the purely consulting engineer from advertising himself in any way, would be the height of injustice. It must be considered essential that the professional man who is allied to a business concern shall not allow his name to be displayed in any advertisement whatever, nor shall the product manufactured by his firm bear his name by way of a trade-mark.

Professional Fees.—The position of consulting engineers is perhaps particularly unsatisfactory. To take the question of fees first. In the absence of any legal status, it is exceedingly difficult to define or establish a scale of fees which shall receive universal recognition. One is frequently hearing of cases where a consulting engineer has been asked to state an inclusive fee for certain work, only to find that it has been undertaken by someone else for a much lower figure. Such a procedure is unheard of in any profession but our own, and points to a lack of unity and professional concord.

Many manufacturing firms at the present time make a practice of giving advice on engineering matters, preparing estimates, and even drawings, free of any charge, if the order for a part of the intended work is placed with them. Such advice is naturally biased, and often results in expensive plant being installed which is quite unsuited for the purpose in view. Such a state of affairs is manifestly unfair to the consulting engineer, as well as detrimental to the interests of the public.

The consultant, for the sake of his professional reputation, would naturally take greater care to consider the real interests of his client, and, acting independently of any commercial bias, would be more fitted to judge what would best suit the requirements of the case. The profession would hold a higher position in the estimation of the public, when once it was realised that the advice given was as independent as that given by any other body of consultants. It would then become an understood thing that a consulting engineer's opinion was not only desirable, but practically essential, and their recognition as a special branch of the profession would be secured.

SUGGESTED REFORMS.—Having thus sketched the chief hindrances to the advancement of the profession, it is now time to outline a scheme whereby these obstacles may be removed.

At the head of such a scheme should be placed the formation of a Central Organising Body, whose duties would be either to deal with problems affecting the profession, as they may arise, or, if deemed more advisable, to delegate their authority to select committees. The institution and composition of this body is the next step to be considered, and here, as in every other case where it may be possible, such organisation as already exists should be utilised to the fullest extent. The three largest and most representative societies at the present time are the Institution of Civil Engineers, the Institution of Mechanical Engineers, and the Institution of Electrical Engineers, of which the first-named, by reason of its greater age and better organisation, stands undoubtedly on a higher plane than the other two. It is, therefore, very desirable, in the first place, that the two latter institutions should place themselves on an equality with the Civil Engineers, since they are in no way inferior as regards the scientific training of their members.

It would be advisable that these three Societies or their Councils should convene a joint meeting for the purpose of appointing a committee of their members to consider the better organisation of the profession, the preliminary expedients to be adopted, and the form which the permanent scheme should take.

The committee would first proceed to organise a central governing body consisting of a president and council. This body should be equally representative of each of the three Societies before mentioned, the members being either nominated or elected by the respective Councils. Vacancies on the central council as they occurred would be filled from the Society affected, so as to maintain the equality of representation. The president should hold office for a limited term, a representative of each of the constituent Societies being elected in rotation by the central council. A member of the central council need not necessarily have sat on the council of the Society which he represents, each council having the right to nominate any full member of their Society as their representative. The central council being complete, it would be advisable that it should endeavour, at the earliest possible date, to obtain recognition as a legalised corporation by Act of Parliament. In the meantime, it would devote itself to instituting such machinery as could deal most effectively with the main questions affecting engineering, arranging for committees to enquire into the needs of the profession, and to consider schemes of reform, so that no branch or subdivision of the profession might appear to be neglected. All such schemes should be as comprehensive as possible, and in view of the fact that engineering is ever developing new spheres of influence, ample provision should be made for future extensions and alterations, subject to the approval of the central body.

In all matters relating to the profession this body would have supreme jurisdiction, its duties being both organising and judicial, though in practice it would probably be found advisable to give as free a hand as possible to the three component Societies in matters specially relating to their respective branches.

Having once obtained a legal status, the central body should turn its attention to the following points :—(i.) Registration of members ; (ii.) education ; (iii.) regulation of fees ; (iv.) organisation of funds for aiding invention and research, etc. An endeavour should then be made to formulate a scheme for the establishment of an information bureau for engineers, and the institution of benefactions for the more needy or unfortunate of its members.

Registration.—A register should be compiled containing the names and addresses of qualified members of the profession, their present occupation, and an outline of their qualifications. No one should be allowed to have his name entered on this register unless he be a *full* member of one of the three Societies and at least an associate member of one of the others. Anyone not thus registered should be legally disqualified from receiving fees as a consulting engineer, and debarred from holding any public engineering appointment. Moreover, any infringement of the laws drawn up by the central body for the protection of the profession, or serious breach of professional etiquette, should make the offender liable to have his name struck off this register, so that he ceases to be a recognised member of the profession.

Education.—Men desirous of entering the engineering profession should be obliged to qualify at certain recognised centres. These centres should be limited to the existing engineering colleges and the universities ; technical and other schools being allowed to enter their pupils for entrance examinations only, as in the case of other professions. At the same time, to prevent any undue hardships arising from these restrictions, ample opportunities should be given to all who may desire to enter the profession, by a liberal provision of scholarships and exhibitions. In this way none need be debarred from becoming engineers by lack of means to meet the educational requirements. The standard of the profession as a whole would tend to rise, while the problem of overcrowding would be solved, as far as it is possible nowadays, since the output of mere rule-of-thumb men would be restricted. Another result would be that a higher value would be set on the qualified engineer, so that he would obtain a better return for his services than he can at present command.

Having passed through a course of theoretical and practical training such as may be deemed sufficient to qualify him as an engineer, and having specialised in some one branch of the profession, the young engineer would now prepare himself for admission to one of the Societies as a preliminary to registration. These Societies, the Institutions of Civil, Mechanical, and Electrical Engineers, would practically remain as at present constituted, but, where their differences are such as tend to place one on an inferior plane to both or either of the other two, such changes should be introduced as would ensure professional equality for them all ; such an equality being essential if engineering is to have that unity which alone could make it hold its own with the other professions. The standard of qualifications for admission to each of the three Societies should be of the same high order, associate membership being by examination only and preceding full membership, except in the case of honorary members. Exceptional merit, of course, would alone admit to the latter class, the ordinary full member attaining that position either by writing a thesis, or by having distinguished himself in professional work in a special manner. The class of student members might or might not be retained, but it would probably be found more convenient to abolish it eventually. The existing members of these Societies would naturally remain on their present footing, but no new members should be admitted after the scheme is once established, except in accordance with the new regulations.

The examiners would be appointed and the examinations conducted as the Councils of the separate Societies should determine, but all appointments and regulations should be approved by the central body. A candidate who has passed the examination entitling him to assume the initials of the " degree " conferred by any one institution, when sitting for his second examination should be exempted from again taking any subject in which he is already qualified, so that he may not be unduly hindered from having his name entered on the register as soon as possible.

A certain amount of practical work in a recognised centre should be insisted on as a necessary qualification of registration, the time so spent to be regulated by the central body. The main points to be borne in mind in all details of schemes relating to engineering education are that, although thorough efficiency should be aimed at, yet its cost from first to last should not be excessive, and the time to be spent in qualifying should not be unduly prolonged.

Regulation of Fees.—The profession once having obtained a legal status, it would not be a very difficult matter to establish a scale of fees for consulting engineers. Such a scale should admit of gradation according to the amount of responsibility entailed, and in every instance where the consulting engineer is required to give a large part of his time to the case under consideration, to the detriment of other work, the value of the time so spent should be taken into account. He should also be entitled to claim reimbursement for all outside expenses to which he may be put—all monetary questions being placed on such a footing that disputed accounts or bargaining on the part of a client should be as impossible as it would be in the case of a doctor or lawyer.

Funds.—It would be advisable to place this matter in the hands of a committee appointed for the purpose by the central body. The committee should concern itself with the question of procuring funds, and their administration ; sub-committees being appointed to deal with detailed schemes of expenditure. In raising funds the generosity of individual members would have to be relied upon to a very large extent, donations and subscriptions, large and small, being invited. As the profession became more fully organised, it would doubtless be found both possible and advisable for the central body to claim certain fees (such as registration fees), and these, together with all money accruing from the work of any department dominated by the governing body, would be added to the central fund.

The funds would be applied (i.) to defray the working expenses of the body as a whole, which should be curtailed as far as might be compatible with efficiency ; (ii.) to the establishment of studentships for the furtherance of research work ; and (iii.) to assist inventors in the development of their patents.

Research studentships should be granted only to members of the various societies who showed special aptitude for such work, and who would be unable to devote themselves to it without such aid. They should be held for a limited time only, which might, however, be extended at the discretion of the Committee.

In existing circumstances inventors are often severely handicapped by lack of means from perfecting their inventions, or placing them on the market, and are frequently obliged to sell their ideas—perfected or otherwise—for a totally inadequate sum, having regard to the time spent on them and the harvest often reaped by the purchaser. The fund allocated to this object should be applied to aiding inventors by putting expert legal advice within their reach for the purpose of protecting their ideas, and also by contributing towards the cost of perfecting the invention. In this way the originator of the idea would secure the credit due to him, in addition to such monetary return as might accrue by the sale of the invention.

Applications from members of the profession in respect of grants for these two purposes would be considered by the committee having control of this branch of the funds, their decision being reported to the governing body, which would finally confirm all such grants. The financial committee should particularly encourage all members of the societies to render private aid, as far as possible, not only by subscription, but by practical assistance. For example, owners of large works might allow parts of machines required for a new invention to be made in their works, charging the inventor with the actual cost of the raw material alone.

When the more pressing questions were settled, the central body should endeavour to deal with the establishment of an information bureau and some scheme of benefactions.

INFORMATION BUREAU.—If it were possible to establish a world-wide organisation for the sole purpose of ascertaining engineering requirements in regard to material and men, its value would be incalculable, and there is no apparent reason why such a scheme should not be self-supporting. It may be contended that the British Consuls abroad, being on the spot, are quite capable of giving all the information required, and that the suggested scheme is not only unnecessary, but would be a needless complication. It is to be feared, however, that these gentlemen have so many other important duties to occupy their time, as to be unable to study the special interests of engineers as a distinct section of the community.

It is at present exceedingly difficult for members of any branch of the profession to discover suitable openings abroad, from the meagre data available ; nor is it easy, when having a post in view, to get accurate information concerning the conditions of living and other cognate subjects. Engineers are often tempted to accept a berth abroad by what appears to be a magnificent salary, and sometimes bind themselves to serve for a definite term of years, only to find on arrival that the conditions are so totally different from those to which they have been accustomed, that it would have been better for them to have remained at home.

Again, British engineers, when competing with foreign firms on their own ground, are often sadly handicapped by ignorance of local requirements materially affecting the design of machinery, etc., owing to the means of transport, the conditions under which it has to work, and the amount of attention it receives in service.

In all these cases a bureau supplying the necessary information would be of the greatest value. It should have its headquarters in London, and should issue pamphlets from time to time, containing the most recent available information based on facts obtained from the Consul or from British residents (members of the profession or otherwise) in that particular country.

BENEFACTIONS.—A sub-committee should be appointed to consider how far it would be possible to organise a scheme for extending necessary financial assistance to the poorer members of the profession, quite apart from educational or similar grants. Any such scheme would naturally be dependent to a large extent on the private enterprise of individual members, who must be encouraged to face their responsibilities in this direction. Thus, in course of time, in proportion as the whole profession prospers, those members whom age, ill-health, or unmerited misfortune render worthy objects of benevolence, should find themselves provided for, and feel assured that, as far as possible, those dependent upon them would not be neglected.

The above rough outline of a scheme by which the engineering profession might be placed on a firm basis, and maintained on an equality with other professions, would, in the opinion of the author, be found workable and efficient. The principal difficulties would arise in the initial stages, and would prove doubly difficult in our case, because the organisation of the profession as a whole has not kept pace with its growth in numbers.

Reforms cannot come at once, nor can they even begin until the need for them is recognised, and no definite move can really be made without the initiative of some strong personality, or the influence of a united and determined body of men ; co-operation will eventually follow, effective schemes being welcomed, and, after due consideration, heartily furthered.

It is, therefore, the duty of everyone who feels strongly on this subject—the improvement of the status of engineers—to take his part without hesitation in any undertaking which has this object in view, and to endeavour, to the utmost of his power, to rouse a real interest in the question amongst his fellows.

This Society, by inaugurating its present essay scheme, sets a very excellent example which others would do well to follow.

It must be borne in mind that unless engineers can be brought to realise the necessity of making a forward move in the near future, the state of the profession will become more and more complicated, and the obstacles in the path of reform increasingly great, so as to delay indefinitely the liberation of the profession from its present anomalous position.

The **President** said that with great regret he had to announce the death, since the last meeting, of two past Presidents, Mr. William Arthur McIntosh Valon and Mr. Nicholas James West. Mr. Valon was one of the oldest of the past Presidents. Mr. West had recently passed through the Chair. Both gentlemen were well known and had done much work for the Society, and he was sure that the meeting would concur with the Council in the vote of condolence which they had passed with the relatives.

DISCUSSION.

The **President** said that the paper was, to a certain extent, different from those ordinarily delivered before the Society. The difference arose from the fact that a special prize had been offered for the best paper upon this particular subject. Possibly some of the members were not aware that through the generosity of the Society's Secretary, Mr. Ackermann, the Council had had a fund placed at their disposal for the purpose of providing a special prize each year for a period of five years. The present paper was the result of the first competition for the prize.

The subject of the paper was one which must appeal to every member of the engineering profession. It was one which certainly should give rise to a very full and able discussion at the present meeting. The papers submitted for competition had been carefully scrutinised by members of the Council, and they had had some difficulty in arriving at a decision as to which was the best. Some of the other papers were of a high order of merit, but personally he was bound to say that he fully concurred with the Council in awarding the prize to the author, and he heartily congratulated him upon having secured the first status prize offered by the Society of Engineers. He (the President) hoped that before long some action would be taken on lines similar to those suggested by the author. Undoubtedly the carrying out of such a scheme would be a step in the right direction, and would put the engineering profession upon a sound basis, which it did not possess at the present time. If those present approved, as no doubt they would, of the general outline of the scheme suggested by the author, the Council would then have to consider what steps should be taken to bring the subject before the notice of the three institutions named. They would be very pleased to have, in the course of the discussion, any suggestions which members might have to make as to how that end could best be attained. Probably the least that could be done would be to send a copy of the paper to every member of the Councils of each of the three bodies. Perhaps some further steps might be desirable. It would be for members to suggest what those steps should be. He had very great pleasure in proposing a vote of thanks to the author for the trouble he had taken in preparing the paper, and for the thought that he must have applied to it, and he had further the pleasure of being able to hand him some books which were the outward and visible sign of the prize which he had won.

The **President** then handed to the author the premium of books awarded by the Society for his essay.

The vote of thanks was carried with acclamation.

The Secretary read the following communication from **Mr. C. Collingwood**:—

This is the age of co-operation, of unions and amalgamations, and we may well look to see if the engineering profession could not be consolidated and established more firmly (1) by closer union within its own circumference and between its own members, (2) by co-operation with other and allied professions.

As a profession is but composed of its individual members, so we can best come to a conclusion concerning the whole by discussing the circumstances of the individual. In the first place, the engineer must be suitably trained and fitted for his calling, not only by much reading but by really practical experience. Whether a man intends to study for Electrical, Civil, or Mechanical Engineering, first of all let the student do his workshops; let him leave school at the age of 16 or 17 and do two years "shops," and then at least four years at college, from 18 to 21, or 19 to 22.

The Institution of Civil Engineers is doing the right thing by raising the standard of qualifications necessary for admission, and let not the qualified man ever think that his education attains perfection or completion. The immense usefulness of keeping in touch with what is being done to-day, and of seeing all one can of works in process of construction or in full activity, is successfully promoted by Societies which arrange visits to works, and not only is the knowledge of the individual extended thereby, but the sympathy between men of the same or allied professions, is widened and deepened. Let us see if more cannot be done with this end in view, on the continent of Europe, or even further afield, by arranging Travelling Scholarships for students, and interchange of visits with Societies abroad. If we would serve our profession and generation we should not only see that the Engineer is suitably trained and fitted, but that he is where he is wanted. There is work for each and everyone in the world, but sometimes it is difficult to find the work we feel we could do. I do feel that much could be done to help men to a knowledge of what is wanted and *where,* and that for this an Engineers' Intelligence Department is needed which would serve the double purpose of assisting a man to discover suitable employment and of suggesting to an employer where he may look to find competent and qualified assistance. Part of the equipment of this bureau might consist of an engineering directory of world-wide compass, and might well include Surveyors and Architects; but the special feature which I should like to see adopted is an index of places abroad, countries and towns, giving the names of engineers on the spot and their occupation, with the work being carried on there, together with public and other works yet requisite, to whom inquiries *re* such work and industry could be addressed. British Consuls abroad are not commercial men and are seldom able to give any advice and assistance in business affairs, still less in engineering matters, but let us take it for granted that a man engaged in surveying, engineering or architectural work abroad would be willing to assist with advice and information any junior member of his profession.

In order that this work may be taken up by the profession at large, could not a conference be called together of Electrical, Civil and Mechanical Engineers, Architects and Surveyors, and a Union formed and an Executive elected, or Commission appointed, by whom all information should be collected on these matters, one of whose duties would be the preparation of an annual publication in the form of a Directory to be issued to all the Institutions of Engineers, in which any alterations occurring should be published and issued monthly so that the information might be always up-to-date?

This Commission should also approach Parliament with the request that Registration be made compulsory in the engineering profession and established by law. This is really very important, not only to protect the engineering community from plumbers and builders posing as hydraulic engineers, and other unqualified persons from similar misrepresentation, but also for the effect it would have of safeguarding the public from disasters resulting from the employment of incompetent persons to draw up and carry out schemes and plans pertaining to the profession of the engineer.

Secondly the question of etiquette stands out in importance and it would not be amiss to solicit the strong arm of the law in co-operation; and the Commission, suggested above, should at the same time present a Bill to Parliament prohibiting anyone to practise as an Engineer, Architect or Surveyor, who is not qualified to do so, and as stated before, duly registered.

Mr. H. Howard Humphreys said that he was present because Dr. Hele-Shaw, who had been invited to open the discussion, was unable to be present, and the Council had kindly asked him to take Dr. Hele-Shaw's place. He congratulated the author upon the admirable way in which he had outlined the case for reform. The author's suggestions were sane and statesmanlike, and could be carried out with a minimum of friction. He would also like to congratulate the Society because this was, to the best of his belief, the first occasion upon which a paper containing such far-reaching suggestions had been read in public before an engineering society. He thought that the generous donor who had placed funds at the disposal of the Society for the next five years was also much to be congratulated on his public spirit and interest in the welfare of his fellow professional men. He (the speaker) had read the paper twice with great pleasure, and in the main he agreed with it absolutely. The points with which he did not agree were quite minor ones. He thought that the reading of the paper marked a step in progress, a step in which all in that room were very much interested. For a considerable number of years the great profession of engineering had been diverging along three lines—purely civil engineering, mechanical engineering, and electrical engineering. A fourth line might perhaps be added, and that was municipal engineering, because municipal engineering occupied a position quite different from that of the others, but was just as important. Some time ago he was of opinion that the proper body to deal with the subject of registration—with which registration he entirely agreed—was the Institution of Civil Engineers, but a suggestion which was thrown out some months previously by Dr. Hele-Shaw had led him to a rather different conclusion, namely, the one at which the author had arrived, and which he had so ably put before them, which was that what was needed was a General Engineering Council composed of members of *all* the societies, rather than a council, committee, or governing body composed solely of members of any one of the bodies. If the " General Council " were nominated from the Institution of Civil Engineers, he could, for instance, imagine himself, as a member of the Institution of Mechanical Engineers, objecting to being governed by the Civil Engineers, and he could also imagine all sorts of complications if any of the Institutions at present existing took the lead, but there would be, he thought, very little objection if they all combined and made a sustained effort to bring about the raising of the status of the profession.

With regard to education, he thought that our public and secondary schools generally were, to a certain extent, to blame because boys were allowed to come into scientific professions very ill-equipped as compared with German boys. The Germans, according to his experience, taught science as a means to an end, but the Englishman was inclined to teach science as an end in itself. This might be very admirable, but it did not do in these days of keen competition He thought that science should be taught with an eye on commerce all the time. That might be a rather low ideal, but at the same time they had to make their bread and butter. As President Roosevelt once said, " If they kept their eyes on the stars they must remember that their feet were upon the earth."

With regard to technical education he did not quite agree with what the author had said, viz., " Technical schools, although they perform excellent work, cannot give their pupils that solid foundation which is so necessary before work of a special character can be entered upon " ; and again, " Let technical schools confine their efforts to training mechanics in theoretical work, and encouraging them to think for themselves." He (Mr. Humphreys) thought that technical schools had a somewhat larger call upon them than that, and in some cases the efforts of those schools had been eminently successful in turning out most excellent engineers. The usual course which was followed in training young engineers in this country was not quite a success as far as his experience went. The tendency was for parents, when their boys left school, to send them to a technical college, and then, at the end of their technical training, to article them for a limited time. He suggested that an inversion of that process was better. He thought that if a boy was articled first and then went to a technical school he would far more readily assimilate the theory of the school when he had a few practical pegs in his mind which required clothing.

The question of professional fees was an exceedingly difficult and thorny one. He did not quite see how a definite scale of minimum fees could be fixed, or, if it were fixed, how it could be loyally adhered to. There were innumerable factors which were bound to be taken into account in settling fees with clients, and he was afraid that it would always be a practical impossibility to adopt a definite scale. " Tendering " for consulting work was a totally different matter. Doubtless cases had come under the notice of everyone in the room where the most barefaced demands had been made by District Councils and other people to obtain tenders from consulting engineers for doing all kinds of work. As he mentioned the matter instances which he could vouch for multiplied in his mind. He thought that if they were asked to tender for fees their obvious duty was to decline to do so point blank.

The information bureau was a point upon which he placed the greatest possible stress. He was immensely interested in the letter which had just been read, and which seemed to him to strike the right note. He supposed that at no time in the history of engineering had things been quite as dark as they were to-day, and he did not know what was going to alter them unless there was a great revival in trade. He thought that an information bureau was wanted almost more than registration or perhaps anything else. Such an information bureau should be sympathetically administered by a man with practical engineering knowledge who had experience of public works and who was more or less a judge of character. He laid particular emphasis on the vital necessity and duty of helping youngsters on. On three different occasions and in the last few weeks he had seen youngsters losing hope, and if anything could be done which would prevent their becoming befogged and giving up what should be essentially a hopeful profession that would be an immense service to the profession generally. Those of them who belonged to either one of the Institutions owed a duty to the youngsters and to their brother professional men. He thought that if there were a central information bureau it should be incumbent upon them to place before that bureau a complete record of a boy's studentship course. If this were honestly carried out a boy would know that if as a pupil he did his level best his chances in the future would be vastly enhanced, and those who wanted junior assistants would feel that they had a court of reference from which they could get absolutely reliable information as to assistants. If such a system were adopted it would command, he thought, the confidence of the would-be employer and give a fillip to the boy to do his utmost. Those of them who had spent part of their lives abroad knew perfectly well the necessity for placing better information at the disposal of British manufacturers, not only as to what was wanted, but with regard to what probably *would be wanted* in any particular part of the British Dominions. Germany had met the difficulty in a very ingenious and simple way. Many of the big firms had combined in sending men to find out what was likely to be wanted and to forestall as far as possible the demands of the market. Those men were in every country in the East at the present time and they were sending reports home which were of immense service in increasing German trade. The information bureau would be of enormous assistance to engineers and to the country generally, because the prosperity of the country depended very largely on the engineering profession. Reforms could not come at once, but there must be strong and sustained co-operation, otherwise there was no earthly chance of getting over the inertia of the bodies with whom they had to deal. He was certain that a great many engineers had lost all hope of ever getting any reform. There was need for tactfully approaching the various bodies and for a certain amount of patient waiting. The Fabians took their policy from a General who bided his time, and he thought that if engineers bided their time but watched and made the most of their opportunities they would get what they wanted, but there must be, as the President had said, a very strong belief in the necessity for reform, otherwise any movement which was started would go all to pieces..

Mr. C. J. Yorath, drew attention to the second paragraph of the paper in which the author said, " Here we have a body of men who, by reason of their education and scientific attainments, are worthy to be ranked with any doctor or lawyer in the land." Did the author mean to convey by that that the collective scientific attainments of members, or engineers as a body, were only equal to the individual scientific attainments of a doctor or a lawyer, because literally that was the meaning of the words ; or did he wish to convey the meaning that the scientific attainments of the engineering profession were equal to those of the medical and the legal professions? If he did how could he reconcile this statement with the statement which appeared under the heading of "Overcrowding." "But engineering perhaps suffers more than others from the constant influx of men lacking sufficient scientific training, having no great love for their work, but apparently tempted by the ease with which a footing may be gained as compared with other professions." In his, the speaker's opinion, therein lay the difference between the engineering profession and the kindred professions of medicine and law, and until unqualified men were refused admission into their ranks, they could not, as a body, compare themselves with other professions. He said "as a body" because that term included all those who termed themselves engineers but who in reality were not.

It would be recognised by most engineers that the defects and shortcomings of the profession which the author specially mentioned were common knowledge, and what they were more particularly concerned with at the moment was as to the best method of remedying those defects.

Before he passed on to a survey of the suggested reforms he would like to say a few words in regard to the multiplication of societies. Hardly a month seemed to pass without an advertisement being seen in their professional papers that some institution or association had been or was about to be formed for some purpose or another. They must ask themselves what was the object of these numerous institutions. Was it to improve the status of engineers? He ventured to think that it was not, but rather that certain persons were desirous of becoming either a Member of Council or President of some such institution or association.

Recently an announcement had been made that an Illuminating Engineering Society had been formed. Perhaps, then, there was a ray of hope that they would be able to enlighten the public upon some of the letters so commonly seen after the names of engineers.

He would pass on to review the reforms suggested by the author. His first suggestion, and he (Mr. Yorath) thought the foundation of all his other suggestions, was impracticable. Did the author think, or did anyone in the room think that the Institution of Civil Engineers after having for so many years striven to place the status of Civil Engineers on a higher plane, would agree to the suggestion for the formation of a Central Organising Body? He did not wish for a moment to disparage the Institution of Mechanical or Electrical Engineers, but while these two Institutions had remained as they were originally formed, the Institution of Civil Engineers had gone ahead and had striven to place, and, he thought, succeeded in placing, its members upon that level of scientific and educational attainment which was common to other professions.

The way in which the author invited the Institution of Civil Engineers to efface itself from the engineering world and be a party to its own murder—for no other results would be obtained by forming a new central body with supreme jurisdiction over all members of the profession—was almost ludicrous.

Not only was the Institution of Civil Engineers recognised by the public as the only qualified institution of engineers, but it was also recognised as such by the Imperial Government.

It was no use insisting upon the future members of the profession being fully qualified when they themselves shirked making themselves so. They knew that it was the easiest course to adopt, but a profession built upon such faulty foundations would be unstable, at least during the present generation, and he took it that it was with the present generation that they wished to deal.

He would like to draw the attention of those present to the remarkable suggestion made by the author in the paragraph dealing with registration. It would be seen that if an engineer was a full member of the Institution of Mechanical Engineers and an associate member of the Institution of Electrical Engineers, or *vice versa,* he was eligible for registration, but if an engineer had qualified by examination and had become an associate member of the Institution of Civil Engineers and was not a member of either of the other two societies he was not eligible for registration.

With regard to benefactions he would inform the author that all his suggestions under this head had for some years been in existence, and had been carried out by the Institution of Civil Engineers.

He did not see that they could obtain that professional recognition which they desired without some self-sacrifice, without the enforcement of a higher standard of educational and scientific attainments, both in respect to present and future members of the profession.

Mr. Percy Griffith said he believed that the invitation of the Council for competitive papers upon this subject was a step in the right direction, but he was afraid that he could not quite agree with the suggestion made by the President that the next step would be definite action upon the lines suggested by the author. The whole question was one of vast complexity, but at the same time it was one of such importance that engineers could not afford to take a single step in the wrong direction. Tactful enquiry was necessary before anything could be accomplished in the direction which they all desired to take. His own practice in the study of scientific matters had been to approach difficult problems by small steps, and, looking back, he was astonished at the great things he had been able to accomplish by that elementary method of procedure. The collection of varying opinions upon the subject before them was an initial step which would assist them in deciding upon the next and probably much more important step. He thought that the decision to award the prize to the author was a wise one, and that they were indebted to him for presenting such a comprehensive view of that difficult subject. At the same time he was bound to deprecate any attempt to move on the lines suggested by the author in regard to the various existing societies. He thought that the author had too much discounted the value and importance of smaller societies. No doubt the motives with which such societies were started were mixed and were not altogether disinterested, but one might as well criticise the whole profession because it was devoting its energy to earning its daily bread, whereas such a combination of the practical and scientific interests was a natural one and was essential in any business or profession whatever. As regards the formation of new societies, he felt that no society could exist unless there was a demand for it. An Illuminating Engineering Society might be extremely useful because the science of illumination was worthy of much greater study than had been given to it. One could multiply *ad infinitum* the subjects upon which it was desirable to co-operate and meet for discussion and mutual assistance. Was it not obvious that successful action must lie in the direction of utilising the combined power of the many different organisations by uniting them into an effective whole? He would advocate federation rather than invidious selection as the proper basis for future procedure. If they desired to see the status of the profession improved progress must be through the co-operation of all its branches and of all technical societies. He thought that the paper and discussion might at any rate guide them on their way and help towards a further realisation of the objects so commonly desired throughout all grades of the profession.

Mr. H. Ross Hooper said that he wished to express his approval of the manner in which the paper had been written. He presumed that they could not take it as an ultimatum of all that might be done in regard to improving the status of engineers. The paper bristled with so many points and suggestions that it would be impossible to attempt to deal with them all. The paper referred to the similarity between the engineering profession and those of law and medicine. He disagreed with that analogy. The professions, he thought, were totally different, and that fact created the difficulty. The legal and medical professions were professions *per se*, but the engineering profession was vast and complex, dealing with the business and advancement of the world, and it was impossible to dissociate the engineer from the business man. Difficulties would arise in attempting to draw any hard and fast line such as registration suggested. It had been said that the engineer was useful and the business man was very useful, but that the engineering-business man was invaluable. They had to appreciate that point in considering what could be done to improve the status of the profession. A proposition in the paper for the amelioration of the present conditions of the engineering profession was that of the creation of a central body. One speaker had suggested that the man who had not a degree or qualifications or who had not passed examinations dropped out automatically, but the experience of those who had had to deal with numbers of schemes all over the country was that every year a great deal of money was wasted through the employment of men who were not engineers at all. That was a point which he thought the profession and the institutions could take up with great advantage, and if they would only take the trouble to set to work upon it they would get a harvest of facts in a short time. The two points which seemed to him to be the whole fulcrum upon which the paper and its proposals turned were the "supreme jurisdiction" and "legal status" of the "central body." He took it that "supreme jurisdiction" could only be obtained through Parliament. They were almighty powers in the engineering profession, and upon them the whole issue of the proposals in the paper very largely turned. It seemed to him that they should not at present attempt any such gigantic measure as a "central body" with those powers. Would not Parliament immediately ask the respective Institutions, "Why are you coming for Parliamentary powers to do this in the aggregate, when you have either failed to effect it in detail, or not adopted that which would appear to be the more obvious and simple course?" It seemed to him that the proper course at the present stage was to proceed slowly and tactfully, and to urge upon the Councils of the Institutions which had been mentioned the importance of bringing before the public and the engineering profession the influence which they ought to exert in regard to every engineering work carried out in this country and in other countries with British capital. The influence of the big institutions ought to be brought to bear to make the qualifications for engineering stricter and to make the public keep their eyes a little wider open, and to ask those who were not an ornament to the profession to remove their capabilities to some other sphere. He did not suggest a system of espionage or police work, but there was no doubt that things were done which were not a credit to the profession. They should see that the man who did that which was not professionally correct was eliminated in the same way as he was in the medical and legal professions. Less dry bones and more vitality were wanted to encourage engineers.

He fully endorsed what Mr. Humphreys had said in regard to the information bureau. No one who had had twenty years' experience could fail to admit that at present there was no system of letting young engineers know what work there was in the country and so helping them on. Older engineers who had managed to get to the top of the tree should pay more attention to their younger and other colleagues who were not so fortunate, instead of leaving them to shift altogether for themselves. When young engineers lost hope it was a very bad thing for the whole profession.

Mr. J. W. Wilson said it was obvious that a paper dealing with the status of the engineering profession should begin with the question of education. They had to go to the very beginning of a boy's career, which was better than trying to improve the status nearer the end. It was a pity that our great public schools did not all do more to help the boy at the beginning of his career. It was lamentable to contemplate the invaluable time and opportunity so often wasted in this way. Those who were engaged at a later period of the young man's life in trying to start him off towards becoming a competent engineer were seriously handicapped. They wanted those who did not need to be taught, for example, the difference between a barometer and a thermometer ; who had some idea of elementary science ; of the value of money and of keeping accounts ; who could spell and write ; and who had been taught to think for themselves, and to assume a certain amount of responsibility. If they could thus get those who were more ready to absorb what was necessary for the engineering profession, years of life would be saved. The fact was that those engaged in training engineers more often than not got young men who were not ready even to begin to learn their profession.

He joined issue with Mr. Humphreys when he said that a student should go first as an articled pupil and subsequently get his experience at engineering shops or elsewhere. It was an acknowledged fact that the most fatal mistake an engineer could make at the outset of his career was to begin working in a groove. A young man must not say, " I am going to be this kind of engineer " or " that kind of engineer " ; for he could not then tell what he was best fitted for ; and even if his father were an engineer he very probably would not know either. What the young man's bent was had to be proved. It was a very common thing for him to think that he should be a mechanical engineer because he possessed good mechanical aptitude; only to find out later that that aptitude was a *sine qua non* for his efficiency as a civil engineer, for which he might be better fitted. He should like to place it on record, as at any rate his experience, that in the long run it was far better there should be no attempt to work in a groove at the outset, but that a broad foundation should be laid in every respect, and that the specialising should follow later on. They all knew engineers who did not care to take youths straight from public schools as pupils, but who stipulated that they should have some previous training in what for want of a better term might he call a " technical " school. It was quite certain that if only a boy could be taught to think for himself, that would go a very long way towards solving the difficulty. Why should he not on leaving school have already acquired a certain amount of business knowledge. .The difficulty of the problem was that life was so short, and that theoretically the engineer must know everything. How should they best lay out two or three years of this period of life so as to give the man a chance in the profession ? They should give him a good combined theoretical and mechanical grounding, find out what he was fitted for, and then let him go at once to actual practical work where he would get experience with engineers who were carrying out such work as he desired to specially follow in his subsequent career.

He also desired to emphasise the important fact that any training of the young engineer which ignored the regulation and development of his personal character was almost worthless. He agreed with what the author had said with regard to engineers not advertising themselves ; but there was a great deal of difference between that and the engineer sinking down to a position where he was practically ignored. They would often see, not in the technical but the daily papers, long descriptions of important engineering works with no mention whatever of the engineer ; and he could not see why they should not protest against this. It would be a delicate thing for a man to write and say, " You forgot to mention that I was the engineer who designed that piece of work," but if they would do it for one another it would be something. Two leading daily papers lately gave a column of description of the recent opening of Blackfriars Bridge. The notices bristled with names ; the contractors were not forgotten, and those who had so much to do with providing the necessary funds all figured, and rightly so ; but there was not the slightest hint that any such person as the engineer had had anything whatever to do with the work. Something should be done to see that their profession got the credit due to them. They ought not to be satisfied with the process that obtained in early Egyptian architectural days when the engineer was not allowed to put his name anywhere because the whole of the credit went to the Pharaoh. The engineer prepared his structure, and the day before it was to be inaugurated, having previously cut very deeply into the stone his own name (with M.I.C.E. and so on after it), he covered it with a nice white surface of the excellent cement that was made in those days ; and he marked in the cement in striking characters the name of the Pharaoh. The engineer thus had the satisfaction of knowing that some hundreds of years afterwards the cement would fall off, and he would get the credit of the structure, when the Pharaoh would be forgotten. At the present day the profession ought not to be satisfied with such posthumous recognition.

Mr. Ernest Benedict said that the paper was a very clever one.

He was rather inclined to be of the same opinion as the gentleman who had spoken up for the Institution of Civil Engineers, because he happened to be amongst the hundred senior members of that Institution, and although they had not gone ahead as fast as they might have done, still they were going very much in the direction which the author thought ought to be pursued. They were gradually raising the status of their members.

He must say that the letters so frequently placed after a man's name were often very confusing. The very fact of a society having been formed would militate against its being more or less obliterated, and he was afraid that anybody who tried to start such an idea would run his head against a very strong stone wall. Would any of the large societies be willing to sink their identity in that of a big scheme? He was afraid that they would not. The vested interests, as they might be called, would be too strong, but there was no reason why all the societies should not combine to bring pressure to bear on the parent societies to improve matters. One reason which had not been mentioned why the Institution of Civil Engineers was not more generally entered was the enormous cost of the subscription, which bore hardly not only on young engineers, but on those who were past work and who still had to keep it up..

He quite agreed with what Mr. Wilson had said as regards the integrity of engineers. That was a point upon which he felt very strongly. He thought that engineers were not to be compared with lawyers or doctors because, with all due deference to those two noble professions, their members were sometimes more or less humbugs. He thought that engineers might very well be classed with the Army and the Navy or the Church, for unless they knew how to manage men and how to keep discipline, and unless their integrity was above reproach they were not really purely professional civil engineers, but something else—perhaps commercial men. He considered that the German military training was invaluable to engineers, bcause it not only taught them to obey their superiors without demur, which was sometimes a very difficult thing to do, but how to manage their inferiors also.

With regard to fees, the author did not put in the word "minimum," which was very important. A comparison could not well be made with the medical or legal profession. Surely fees varied very much. He knew a case where a consulting engineer, Sir Benjamin Baker, got £100 for saying one word —"No"—when he was asked whether the structure at Earl's Court which fell down during a storm should be re-erected. They all knew the struggling medical man in the poor districts of London who charged 1s. 6d. a visit and was very glad to get it. There was really no standard fee for either doctors or lawyers. As he understood it, in the Navy a boy came before a Board, who asked him questions and who judged from his answers, which were sometimes unexpected, what kind of character he had. He had never heard of that sort of examination for engineers, but he considered it much more important than any other kind.

With regard to advertising, the point was drawn out a little too fine, he thought. After all, a man who read a paper was indulging more or less in advertisement, and his name went all over the world as the author. Why should he not also be known, as the last speaker had suggested, as the author of a work like Blackfriars Bridge. He did not think, however, that a consulting engineer, as such, should advertise. In any American paper they would see the advertisements of engineers, and he believed that engineers were thought just as much of there as here. Engineers should not be in the least ashamed of advertising the fact that they were engineers.

Specialising was an exceedingly good thing, and Illuminating Engineers, for instance, should meet together and compare notes. He thought that there was a great deal of overlapping and that the Institution of Civil Engineers embraced every sort of engineer. For instance, Sir William Preece was above all an electrical engineer, but he had been President of the Institution of Civil Engineers. That institution, indeed, included contractors, who at one time were considered quite ineligible. He had a great opinion of them as long as they were the right sort of men, and he thought that they should be honoured above everything if they were men like Sir John Jackson, Sir John Aird, and Sir William Arrol. Surely they were at any rate as good as the ordinary run of civil engineers.

Mr. Reginald Brown said that with regard to the multiplication of societies and the misuse of the word " engineer " the Institution of Civil Engineers, as the premier body in the Civil Engineering profession, should take the lead. Probably the proper course would be to bring the whole matter before the Council of that Institution with a view to their taking some action for the improvement of the status of the profession. The use of the word "engineer " should be confined if possible to members of chartered institutions, of which there were very few in this country. Other institutions simply adopted their own names and were registered at the Board of Trade as limited liability companies. He agreed that often the letters after names were really unintelligible. By all means let them have societies to represent illumination, ventilation, municipal engineering and so on, but the members of those societies should place after their names simply " Member of " so-and-so. He thought that if they were compelled to put after their names the word " limited " very few indeed would use the titles.

Mr. H. Conradi said that it seemed to him that the idea expressed in the paper had been expressed many years ago.

The Institution of Civil Engineers was offered a sum of £20,000 by Sir William Siemens to erect a building in which all engineering societies could meet together professionally and for social intercourse. He thought that the paper was a very excellent one and if it were possible to carry out its proposals it would be of great value. Means should be found for bringing projected engineering works to the notice of members of engineering societies, In this country there was not much scope left for large engineering undertakings, but they were required in all British possessions. If the connection between the mother country and the British dominions could be more intimately established and greater facilities given for the transport of goods and passengers, it would have a beneficial effect on the profession.

Some system of obtaining information with regard to foreign and colonial appointments for engineers would be of great assistance in alleviating the present unsatisfactory state of employment.

Mr. A. S. E. Ackermann wrote saying that the following were the chief points on which he wished to lay emphasis :—

That by the registration of any profession or trade the amount of work in that particular calling was not either increased or decreased, but such work as there was, was confined to those who were properly qualified to deal with it, and who had gone to considerable trouble and expense in order to qualify to do such work. The public benefited by having at least a certain minimum skill and knowledge guaranteed to them when employing members of a registered profession or trade.

The strict etiquette and *esprit de corps* observed in the legal and medical professions was the cause of their being in much more satisfactory position than other professions. It was easy to laugh at some of the restrictions imposed on barristers and medical men, but such restrictions raised the whole tone and honour of those professions, so that it was a frequent occurrence that a man read for the law on account of the social standing that it gave him, whereas nobody ever thought of reading for engineering or architecture with the same object in view.

It had been said that you cannot make a gentleman by Act of Parliament, but a barrister in reply remarked that you might as well tar those who were not worthy to be members of any particular profession so that the public might distinguish the sheep from the goats.

The question of advertising was covered by what had been said before. Barristers and medical men did not advertise, but for all that, they got all the cases and patients that there were for them to have and saved themselves the large expense there would be if it were the practice for them to advertise.

Mr. Ackermann said that while he was a strong advocate for the registration of engineers, nevertheless, he was convinced that registration would not do all that was desired. On the other hand an immense amount might be done by the voluntary action of engineers themselves. A vast amount of the organisation of the professions of Law and Medicine was of a purely voluntary nature and did not depend in the very least on the fact that those professions were registered, and the effects of such voluntary organisation in those callings, especially as regards fees, were common knowledge. Consider the enormous influence of the British Medical Association, which did not (as was often said in explanation) embrace the whole of the medical profession, or even if it did so now, certainly did not do so at first. Their membership was about 21,000 out of a total of some 33,000 qualified medical practitioners who were eligible for membership. Mr. Ackermann said he had had an interview some time ago with Mr. J. Smith Whitaker, the Medical Secretary of the British Medical Association, who very kindly wrote to him on the subject as follows :—

In some matters you engineers would have the advantage of us because you start, as I should imagine, with practically a "clean sheet," whereas we have found our hands tied by the traditions of centuries. On the other hand, those traditions have, of course, in some respects been a great help, particularly the tradition of "esprit de corps," which, notwithstanding many failings, has undoubtedly existed in the medical profession for a very long time. Even now we have very little in the shape of a written code of medical ethics. At every turn in deciding cases our Ethical Committee has to fall back not upon any code, but upon principles generally recognised among the profession, and the only guarantee for the soundness of their judgment is the fact that they are elected in a representative manner and that their findings, based upon those principles, are in fact accepted by the general body of the profession as an expression of principles, the validity of which they recognise.

In considering the work before you, you will doubtless carefully distinguish between the creation of any statutory body with legal powers as regards the government of the engineering profession and the work which may be done by voluntary organisations.

In the medical profession we have the General Medical Committee, a body which is the creation of the Medical Acts, and has certain disciplinary authority defined by those Acts.

Next we have the various Universities, which for the present purpose may be simply regarded as degree-granting bodies having no disciplinary powers over their graduates, and there are the various Royal Colleges, the oldest of which, the Royal College of Physicians, received its charter in the reign of Henry VIII., who not only have the power to grant diplomas, but have also very considerable disciplinary powers over their diplomates.

Then you have the British Medical Association, a purely voluntary organisation registered at present under the Companies Act as a company not formed for profit, and exercising any authority that it possesses over members of the profession, simply through (a) its inherent power over its own members, and (b) the influence which its traditions and large membership are able to give it over the minds even of non-members.

Then you have many so-called "Defence" Societies, the primary object of which is to defend at law the personal interests of their individual members when attacked in their professional capacity.

You will readily understand what a tangle this multiplication of bodies creates when we have to deal with any question of alleged unprofessional conduct.

If my supposition is correct, that you are beginning your work practically with a "clean sheet," you would certainly be well advised to avoid any such multiplication of authorities. I cannot say, however, reasoning from the analogy of the medical profession, that it would be wise to attempt to create only a single authority. For example, in our case, even were there any prospect of Parliament consenting to such a thing, I do not think it would be generally regarded as desirable that the British Medical Association should be invested with the powers of the General Medical Council as has been done in the somewhat analogous case of the Incorporated Law Society.

We can do many things as a voluntary organisation, in the way, for example, of maintaining the standard of proper remuneration which would be looked upon with great jealousy by the public if we enjoyed any statutory disciplinary power. There is much to be said for retaining a statutory body with the authority to strike names from the statutory register for grave offences against the honour of the profession, or against the public interest in the most obvious sense of those terms, while leaving it to a voluntary organisation to deal with matters which may be considered primarily to affect rather the material interests of the profession, such as underselling and the like. We should, of course, be quite prepared to maintain that in the long run underselling is to the detriment of the community as well as to the profession, because it means eventually the deterioration of the profession. But one cannot conceive Parliament allowing a body armed with statutory powers to use those powers as a means of enforcing standard rates.

REPLY.

The **Author,** in reply, said that he congratulated himself very much on the fact that the paper had provoked so much discussion and kindly criticism. It occurred to him, as he supposed it had occurred to the meeting long before, that the discussion had been much more enlightening than the paper itself.

November 5th, 1909.

EDWARD JOHN SILCOCK, PRESIDENT,

IN THE CHAIR.

SOME OBSERVATIONS ON THE CHEMISTRY AND BACTERIOLOGY OF SEWAGE PURIFICATION.

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THE purpose of this paper is to refer those Members of the Society of Engineers who are interested in the subject to a few fundamental principles connected with the purification of sewage.

In no department of human activity does Nature forgive transgression of her laws. Ignorance is not admitted as an excuse for transgression. In dealing with Nature it is left to man to find out why his ears are boxed. This is the warrant for scientific research, a cult which is not yet, in this country at least, much understood. A momentary wave of excitement is created perhaps when some discovery is announced that carries with it a practical commercial value, but the interest is only transitory and confined to the immediate issue. The value of the accumulated results of countless workers in a hundred fields—results which alone make further discovery possible—is wholly unperceived.

In no field of applied science is the need of research more pressing than in that of the purification of sewage. If demonstration of the truth of this statement be demanded, it is only necessary to refer to the numberless contradictions and masses of unscientific chatter met with in books and periodical literature on points of the most elementary nature. In the solution of complex problems the greater the complexity the clearer must be the vision and the more exact the knowledge of the worker.

Sewage purification is from first to last a matter of biological chemistry committed to the mechanical devices of the engineer.

In this work chemistry and bacteriology cannot be separated. The bacteria engaged produce their effects through enzymes—chemical bodies liberated as secretions or excretions in the ordinary cycle of metabolism.

In bacterial action, as in all other activities, the two fundamental laws of the inorganic world, viz., the conservation of matter and the conservation of energy, are obeyed. The bacterial cell, like all cells, is an energy machine or transformer Recent advances in physical chemistry, especially in the properties of solutions, colloids, and crystalloids, have shown that all biological problems are governed by laws as immutable as are the most fundamental inorganic phenomena. The cell consists of colloids and crystalloids in common solution in water. The reactions occurring in the cell are reactions in solution. Our knowledge of cellular activities must be based on a knowledge of the properties of solutions both of colloids and crystalloids, of reactions in solution, of the velocities of such reactions, and of the conditions of equilibrium, of the mutual effects of crystalloids and colloids upon one another when in common solution, and of the effect of the living cell as an energy transformer on osmosis and diffusion.

For any type of engine, if the load be taken off, the engine races ; as the load is increased the velocity lessens, and with a sufficiently large load movement ceases. When the potential differences of the opposing forms of energy become greater than those of the form of energy driving the motor, the engine must stop, or, if capable of doing so, run in the opposite direction. The supply of energy necessary for all the changes observable in living structures arises from chemical reactions occurring in solution. The velocity or intensity of reaction depends on the values of the potential factors and the facilities provided by the system for interaction. The three forms of energy which normally undergo alteration in value when a chemical reaction occurs in solution are chemical energy, heat energy, and osmotic energy. Their algebraic sum must ever be zero.

In connection with velocity of reaction the conclusion may be drawn that in the case of each enzyme there is in dilute solutions a range of concentration throughout which the activity increases approximately directly as the concentration, and as the concentration increases a further period in which there is also an increase but at a less rapid rate than the concentration, and that finally a maximum effect is obtained beyond which increasing the concentration has no action in increasing the activity.

For a single substance α, undergoing conversion into two substances β and γ, the common type of action of enzymes, it can be shown that

$$\frac{dx}{dt} = k_1\left(\alpha - x\right) - k_2\left(\beta + x\right)\left(\gamma + x\right)$$

where α is the molecular concentration of the single substance, β and γ molecular concentrations of the two into which it is converted, and x the change in concentration in time t.

Where two substances react to form two or more, provided there is no back reaction, the velocity equation becomes

$$\frac{dx}{dt} = k\left(\alpha - x\right)\left(\beta - x\right);$$

or, if α and β are in equimolecular concentration α at the beginning, it is

$$\frac{dx}{dt} = k\left(\alpha - x\right)^2.$$

For a trimolecular reaction the equation becomes

$$\frac{dx}{dt} = k\left(\alpha - x\right)^3,$$

and for an n molecular reaction

$$\frac{dx}{dt} = k\left(\alpha - x\right)^n.$$

Enzymes are catalysts produced by living cells, and as catalysts, change the rate of such reactions as take a measurable time to reach their completion. The addition of a catalyst serves to hasten the end of a reaction, which, if sufficient time were allowed, would complete itself alone. Whilst the degree of acceleration of a reaction is proportional to the concentration of catalyst present, at the same time an exceedingly minute quantity of the catalyst is capable of inducing a measurable increase of activity. In the field of applied chemistry, with which at the moment we are concerned, numerous groups of catalysts are found, succeeding each other in the different phases in all degrees of concentration, and working under conditions, now favourable, now highly adverse. Some of these are inorganic, the bulk are enzymes.

Our knowledge of the action of enzymes is not by any means new. Dubrunfaut, in a paper entitled, " Ueber Verwandlung des Stärkemehls im Zucker durch Malz," described in 1830 how he converted starch into sugar with a solution of malt, obtaining the same results as Kirchoff got in 1812 by the action of concentrated acids. In 1837 Berzelius concluded that the transformation of sugar into alcohol and carbon dioxide by a ferment was not of the nature of a double decomposition between the sugar and ferment, but resembled certain inorganic phenomena, more especially the splitting of hydrogen peroxide by platinum, and that in living plants and animals thousands of catalytic processes take place between tissues and fluids. These views have been supported by Bunge, Traube, Ludwig, and many other physiological chemists.

Many enzymes are found at the end of the reaction apparently unaltered. Enzymes, unlike inorganic catalysts, are rendered inactive by temperatures running according to conditions from 60 deg. to 100 deg. C. ; if, then, changes continue to show themselves in a system after boiling, they are not due to enzymes.

Enzymes do not pass through parchment paper ; they are colloids. Bodies in colloidal solution consist of particles so minute as to be ultra-microscopic. If a strong beam of light be passed through a permanent colloidal solution, the particles will appear as a bright streak in its path, and the light sent out at right angles to the beam will be found to be polarised, i.e., the particles reflecting the light are smaller than the wave length of the beam. Zsigmondy has estimated that the particles of certain colloidal gold solutions have a radius of one-hundred-thousandth of a millimetre. It would appear that no distinct partition can be made between matter visible to the naked eye, in ultra-microscopic particles and in molecules, so far as the magnitude of a particle is concerned. An electric distinction, however, exists between molecules and colloidal particles ; whereas the charge of a molecule is always constant in amount, and of the same sign, the charge of a colloidal particle is variable both in quantity and in sign. Perhaps the most important physical feature of colloids is the enormous surface presented by them in proportion to their mass ; hence their powers of surface attraction or adsorption. When solids are immersed in fluids, the film of fluid in contact with the fluid behaves as if stretched. Now, if this film be broken at any point by a third body, the total surface tension is lowered. If, then, in a liquid containing in solution a body which lowers its surface tension colloidal particles be placed, and if the body accumulate at the interfaces of the particles and liquid, as it can be thermodynamically shown to do, it is plain that the surface tension at these places will be lowered. The phenomenon of adsorption plays an important role in connection with colloids, and wherever surfaces are in contact with liquids or gases.

Colloids are not absolutely indiffusible, but possess a small osmotic pressure. They are, moreover, extremely liable to change. Enzymes in solution lose their activity more or less rapidly. Many, even when air-dried, like trypsin, slowly lose activity, and can only be preserved for a length of time in a cool and dark desiccator. Colloids take up by adsorption other colloids, but not in direct proportion to concentration. In the more dilute solution relatively more of the compound is taken up. Many processes of the kind known as reversible or balanced occur in the living organism, that is to say, after a body has been hydrolysed it may be resynthesised. It is the merit of Croft Hill to have first demonstrated a synthetic process taking place under the influence of an enzyme. Now it appears to be merely a matter of finding the proper conditions in order to show that synthesis is effected by all enzymes. Kastle and Loevenhart have shown the reversibility in action of lipase in fresh watery extract of pancreas on a mixture of ethyl alcohol and butyric acid, when ethyl butyrate was produced.

Under appropriate conditions enzymes are able to synthesise bodies which they hydrolise, but there is no evidence to show that they can synthesise other bodies. In such cases synthesis takes place under conditions of high concentration of the products of hydrolysis. Since the final equilibrium is not the same in catalysis by enzymes and in catalysis by acids, the enzyme probably enters into the constituents of the equilibrium. Adsorption seems to obtain between enzyme and substrate and between enzyme and products. Some enzymes are so unstable that they become destroyed during the reaction, e.g., trypsin disappears after prolonged action.

In the animal body and outside there is a large number of protein-splitting enzymes, and there can be little doubt that through a reversible action these take part in protein synthesis. Here a marked distinction is to be made between enzymic and acid hydrolysis: an animal can maintain its nitrogen content on a diet composed of the products of tryptic and ereptic digestion, but not on the products of acid hydrolysis. Enzymes, it would appear, do not uncouple certain groups in the protein molecule; and when these groups are uncoupled by acid hydrolysis it is impossible for the body to unite them again.

Into the subjects of co-enzymes and anti-enzymes the limits of this paper will not allow entrance. Suffice it to say that the living cell, through the assistance of these bodies, is capable of effecting at ordinary temperatures many chemical reactions which otherwise would require high temperatures and powerful reagents; that enzymes are subject to the laws of catalysis; that surface action (adsorption) is always largely in evidence; that their colloidal nature leading to destruction by heat demands for their greatest activity an optimum temperature; that in a large number of cases, if not in all, the enzyme and substrate during a portion of the reaction time come together as a colloidal adsorption-compound; and that in every particular enzymic action is the same in vegetable tissues as in animal.

From this brief consideration of the nature of enzymes, bodies which constitute the most important type of machinery in that natural laboratory in which dead organic matter is oxidised, let us turn for a moment to the work which it is their province to execute.

Sewage is composed of a watery mixture of proteins, carbohydrates, fats, and various inorganic matters. The organic substances exist in solution and in particulate form. Colloidal solutions are constantly encountered. Sewage is charged with bacteria and enzymes, and when of domestic type contains in addition to air, water, and soil organisms, dominant types indigenous to the human intestine. In the fresh sewage of a large town the organisms of typhoid, dysentery, and other intestinal diseases are rarely absent. The notable constancy of B. coli, B. enteritidis sporogenes, and streptotocci has conferred on these varieties the title of sewage indicators. Be it here remarked that certain anærobic sporing organisms, like the B. aerogenes capsulatus and the B. putrificus (Bienstock) are also very constant and also capable of setting up under favourable conditions putrefactive fermentations in the lower segment of the intestine of the person who swallows them. The existence of chronic intestinal putrefaction as a type of disease is now thoroughly established, and the first element in its prevention is obviously avoidance of putrefactive contamination of water and food. Typhoid, dysentery, and cholera are not the only diseases borne by water polluted with domestic sewage. With the progress of civilisation and centralisation of man in cities there is a corresponding increase in chronic infections of the digestive tract.

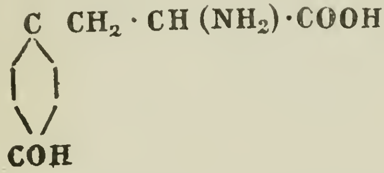
Where population is sparse the disposal of human excreta is a matter of little difficulty. The soil receives them and deals with them effectively. In point of efficiency no artificial method can compare with this natural one. All that is required is to commit the materials to earth at a safe distance from the dwelling and from water courses.

In the superficial foot or two of soil is initiated and completed that complex set of chemical and physical reactions which transforms putrescible proteins harbouring pathogenic bacteria into harmless nitrates in which no disease-producing bacteria can live, and which transforms also infected carbohydrates and fats into carbon dioxide and water.

Sewage carries the organisms and enzymes of its own putrefaction. The chemical reactions of the putrefactive stage are closely analogous to those which effect the digestion of foodstuffs in animals.

Native proteins undergo cleavage or dissociation. Such cleavage is produced by acids, alkalies, oxidising reagents (as permanganates and peroxides), halogens, sulphur, numerous enzymes, putrefactive bacteria, and the metabolism of plants and animals exclusive of bacteria. Protein dissociation may be regarded as occurring in two stages, primary and secondary.

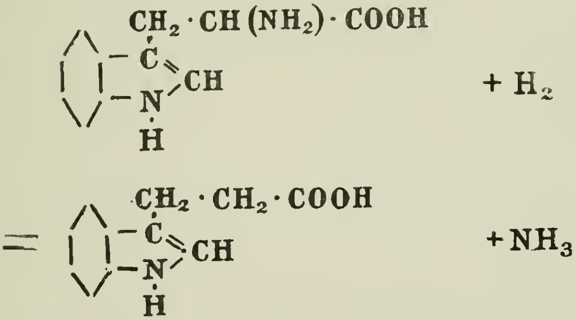
The primary products include albumoses, peptones and peptides, all of which resemble more or less the mother substance in that the carbon chain remains intact, and as far as we know the nitrogen remains unchanged. These can be further split into secondary bodies possessing little resemblance to the originals, viz., amino-acids. All these substances are to be found in sewage, and are the hydrolytic products of the action of pepsin, trypsin, erepsin, putrefactive bacteria, B. coli, etc., on proteins. It is impossible to refer to methods for the detection and estimation of dissociation products, but here it may be remarked that the chemist who would in future handle sewage intelligently will require not merely to know such methods in theory, but to use them practically. It is well to recognise that truth is discovered only as a rule by the use of methods. By mercurous nitrate in nitric acid, a solution first used by Millon in 1849, it has been demonstrated that tyrosin, phenyl-p-hydroxy-α-amino-propionic acid



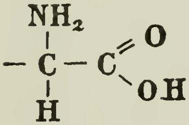
is contained in all albumins except gelatine and certain albumoses and peptones ; the reaction is given by any benzine derivative in which one hydrogen atom has been replaced by hydroxyl.

Bacteria act in the first instance on albumins as do trypsin and boiling acids, i.e., they form at first albumoses and peptones and subsequently amino-acids. The amino-acids are then converted into the corresponding fixed acids with elimination of NH_3 in the same manner as if they were treated with fixed alkalies.

Tryptophane (Indol-amino-propionic acid) is split by anaerobic bacteria into indol-propionic acid, and ammonia.

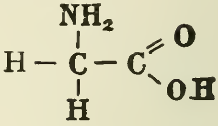

$CH_2 \cdot CH(NH_2) \cdot COOH$
C
CH
N
H
$+ H_2$
=
$CH_2 \cdot CH_2 \cdot COOH$
C
CH
N
H
$+ NH_3$

With a few exceptions all the primary dissociation products of albumins are α-amino-acids of the general configuration



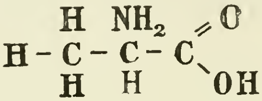
which configuration determines their behaviour and that of the entire albumin molecule.

The simplest amino-acid is amino-acetic or glycocoll discovered by Braconnot in 1820.



$$\mathrm{H-\overset{\displaystyle NH_2}{\underset{\displaystyle H}{C}}-C\begin{matrix}{\nearrow}O\\ {\searrow}OH\end{matrix}}$$

From this it is but a step to amino-propionic acid or alanin



$$\mathrm{H-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle NH_2}{\underset{\displaystyle H}{C}}-C\begin{matrix}{\nearrow}O\\ {\searrow}OH\end{matrix}}$$

After these may be mentioned amino-valerianic, isobutyl-α-amino-acetic (leucin), aspartic, glutaminic, diamino-propionic, lysin, arginin, and histidin, all dissociation products of protein and when represented by their constitutional structure all long and well known to the organic chemist.

The merest glance at the constitution of these bodies will show how readily NH_3 can be split off. Nasse, who in 1872 demonstrated the manner in which NH_3 is formed by the cleavage of proteins, has lately pointed out that it should be reckoned both as a primary and as a secondary dissociation product. It is needless to dwell on the value of this remark to the sewage chemist. From the standpoint of epidemiology ammonia may indicate the presence of highly dangerous organic substances or others the most innocuous. Amino-acids are acted on by bacteria in another way: CO_2 is split off. Methylamine found by Mörner and Emmerling in certain bacteria is doubtless derived from glycocoll in this way: $NH_2 \cdot CH_2 \cdot COOH = NH_2 \cdot CH_3 + CO_2$

The production of NH_3 and CO_2 may go on simultaneously. A part of the ammonia of mono-amino-acids is split off and used for the conversion of other mono-amino-acids into diamino-acids; thus aspartic and glutaminic acids are converted into asparagin and glutamin.

Did space permit it would be instructive to consider the constitutions and behaviour of the cystins and sulphur alcohols or mercaptans and their transformation into sulphuretted hydrogen and ammonia.

In 1838 Berzelius introduced the term humin as a substitute for ulmin and gein, which he had previously used in describing certain deeply coloured constituents of humus or mould. These substances are derived not only from proteins, but also from carbohydrates. Twenty-five per cent. of cane sugar may be converted into humin in a few hours. These bodies are insoluble in water and acids, but soluble in alkalies, from which they may again be precipitated by acids. However derived they are always rich in C and poor in H.

The fermentation and oxidation of carbohydrates and fats are simple operations when compared with the corresponding changes in proteins. In both groups the C and H are ultimately oxidised to CO_2 and H_2O. The hydrolysis of the commonly occurring carbohydrates is fairly rapid in sewage whether in tanks, soil, or filters, and under ordinary conditions is always completed before that of the proteins. Cellulose is practically the only resisting substance, and where it occurs in large quantities it should be treated specially by artificial hydrolysis. The number of bacteria capable of splitting carbohydrates is very large, and the gases evolved vary with different groups. In tanks and contact beds, whilst full, hydrogen and marsh gas predominate, whilst in percolating filters and efficient soils carbon dioxide appears in greatest abundance. Much of the CO_2 formed in tanks unites with NH_3 to form $(NH_4)_2CO_3$. The time required for the oxidation of fats through the stages of free fatty acids and salts of fatty acids is so long compared with the time allowed by present-day methods for the purification of sewage that these bodies are best separated and treated apart. There are several groups of vigorous sporing bacteria capable of splitting neutral fats into free fatty acids and glycerine, one of which the author has studied in connection with the problem of the prevention of rancidity in tallow. A second reason for the cutting out of fats is that the glycerine produced in hydrolysis acts as a bactericide to liquifiers of nitrogenous products. Several groups of bacteria known to produce acetic, butyric, and other homologous acids have been studied and used in the manufacture of dairy products. If in sewage operations, especially in warm weather, fats be allowed to enter tanks and filters, serious nuisance may be caused by the liberation of foul-smelling acids and by choking portions of the filters for a time with undigested fatty particles. The presence of fat is not congenial to the growth of pathogenic bacteria ; even the resistant tubercle bacillus fails to flourish in it. The presence of protein is so indispensable to the growth of all bacteria, more especially to pathogenic forms, that it may be definitely concluded that where the protein is completely oxidised no danger can arise bacteriologically from carbohydrates or fats in any form. And it is for this reason that discussion of their hydrolysis and oxidation is so quickly dismissed.

During the transformation of nitrogenous organic matter into nitrates, whether in soil or on an artificial sewage bed, it will be found that there is a continual diminution in the total number of bacteria, and constant change of type. The organisms concerned in the early phases can be cultivated on the ordinary laboratory media ; those engaged in the late phases do not grow on such media. As the environment changes from phase to phase groups of organisms disappear, and new types take their place. Each type possesses an optimum set of conditions including temperature, moisture, quality and quantity of food, oxygen, etc.; or, if anaerobic instead of oxygen, quality and quantity of oxygenated bodies to be split. It is possible by a selected dietary to control qualitatively and quantitatively the bacterial flora of the human intestine; by modifying correctly the conditions of any stage of sewage purification it should be also possible to control its bacterial flora. With the passing of the primary and secondary dissociation products of proteins the putrefactive bacteria gradually disappear. The fact that sewage effluents are rich in these organisms in no wise weakens this statement, but merely indicates that the organisms have recently been in contact with putrescible matter.

When sewage reaches the purification ground a considerable amount of the proteins have already been converted into albumoses and peptones. From these last amino-acids are formed which in turn give rise to ammonia, free nitrogen, and organic acids. The acids and ammonia form ammonium salts, which are readily broken up into carbon dioxide, water, ammonia, hydrogen, nitrogen, and marsh gas, the last three of which escape with some of the ammonia and carbon dioxide, leaving the rest of the ammonia and carbon dioxide united with the mineral elements in the solution or combined as ammonium carbonate.

The increase of ammonia in sewage on standing and the ammoniacal fermentation of urea and uric acid have long been common knowledge in sewage work. There is now much experimental evidence to show that most species of bacteria in sewage and soil are capable of forming NH_3 from organic matter. The careful work of Miguel, Leube, Marchal, Chester, Warrington, Sewerin, and others has completely demonstrated this point. During the formation of ammonia free nitrogen is liberated. Hugonenq and Doyon found that B. typhosus and B. tetanus evolve quantities of free nitrogen from nitrogenous solutions; and the gases emitted from septic tanks have been found by different observers to contain varying quantities of free nitrogen ranging from 16 to 61 per cent. On the other hand, Chester proved that a number of sewage bacteria under certain conditions are able to fix large quantities of atmospheric nitrogen. There is experimental evidence to show that nitrogen is liberated from nitrated solutions, and that in some instances this evolution is due to interaction between some of the oxides of nitrogen and amino-acids. Since the year 1862, when Gopplesröder published in Poggendorf's Annalen a lucid account of denitrification in rich soils, there has grown an enormous literature on this subject; and in recent years several able observers have added exact information by isolating and studying the denitrifying properties of individual and pure cultures. Maasen published, in the Centralblatt fur Bakt., in 1902, a report embodying most painstaking work on 109 species of bacteria, 85 of which were able to produce nitrites from nitrates; and Gage, of the Massachusetts Board of Health, in 1901, stated that of 5,300 cultures isolated at the experimental station, 85 per cent. were able to reduce nitrates more or less completely. Stutzer and Jensen pointed out that a small quantity of organic matter is necessary in solutions for cultures of bacteria to reduce nitrates actively.

Certain bacteria reduce nitrates to nitrites and ammonia; others reduce nitrates and nitrites to N_2O and NO; and others evolve free nitrogen gas from ammonia. When pure cultures of the last group are grown in 1 per cent. peptone broth containing 0.25 per cent. KNO_3, large quantities of N gas escape. It has been shown that Stutzer's B. denitrificans decomposes nitrite, but not nitrate; B. coli reduces nitrate to nitrite; hence a mixture of the two produces nitrogen from nitrates.

Mair, to whom the author is indebted for a specimen culture of his bacterium, has isolated an organism from sewage which reduces nitrates to hyponitrites. Where there is a maximum of oxygen supplied, as in the sprinkling operations, nitrification predominates. But where oxygen is not freely provided, as in contact beds, denitrification appears. This explains why a contact bed gives less nitrate in its effluent than a percolating bed. Nevertheless the effluent of the contact bed may be quite as good as that of a continuously working percolating bed by reason of the large amount of free nitrogen that has escaped.

Working under continual aerobic conditions with distilled water polluted with such definite compounds as Rochelle salt, asparagin, and urea, Adeney has shown that no loss of nitrogen takes place in dilute solutions, and concludes that the escape of free N which occurs in the filtration of sewage can only be accounted for by the much more favourable conditions for oxidation that obtain in the latter.

It may be advantageous in some cases, as at Belfast, to transform as much of the nitrates and ammonia as possible into free nitrogen. Gage has shown by careful experiments that a considerable majority of the bacteria in sewage and in effluents, and in material from sewage filters, are able to produce NH_3 from peptones and to reduce nitrates.

The amount of NH_3 produced by Gage's different cultures ranged from 0.0 to 18.0 parts per 100,000, and the rate of ammonia production varied considerably. Some of the cultures reacted as early as the fourth day, whilst others failed to react until after periods of ten to fourteen days. Like phenonena were noted with regard to the reaction of the cultures on nitrates. Some cultures were found to reduce nitrates to nitrites, ammonia and free nitrogen from the start, while with others the reduction occurred consecutively, and with still others one or another of the reduction products did not occur during the period over which the examination of the cultures extended. In a few instances nitrites were produced in quantities greater than the amount of nitrates, pointing to the nitrification of organic matter either by the bacteria or by some undetermined secondary reaction. Denitrifying bacteria carry on their functions aerobically and anaerobically.

The conversion of ammonia into nitrites, and of nitrites into nitrates, was first studied in this country by Warrington and afterwards on the Continent by Winogradsky. Two groups of organisms were discovered and named after their functions nitrous and nitric organisms. These bacteria are somewhat difficult to grow in pure culture as they do not reproduce themselves on the ordinary laboratory media. A small quantity of organic material was at first found to inhibit their growth, more especially in the case of the nitrite formers, and the presence of ammonia to retard the growth of the nitrate formers. But recent observations made by Winogradsky, and Boullanger and Massol, point to the conclusion that in nature the nitrite former takes on symbiotic functions with ordinary soil bacteria, whereby organic matter fails to retard its activities, and that in the case of the nitrate former ammonia has little power of interference once the organism has had a vigorous growth established. In 1905, Muntz and Lainé brought to light a point of considerable interest, viz., that they did not reach a limit in their experiments where an accumulation of nitrates hindered or even interfered with the process of nitrification. This requires confirmation. These experiments further showed that the humins above mentioned play an important role in nitrification. Working with humus, garden soil, argillaceous soil, and silico-calcareous soil, they found that the nitrification in humus far exceeded that in any of the other soils.

The following numbers give the relative nitrifying powers of the soils quoted :—

Humus	209
Garden soil	90
Argillaceous soil	40
Silico-argillaceous soil	37

Where the oxidation of sewage is slow by reason of scarcity of oxygen, as in rivers, two separate and progressive stages of change may be noted ; first, the formation of carbon dioxide, water, ammonia, and certain humin bodies ; and second, the oxidation to nitrites, nitrates, and a small quantity of CO_2 of the newly formed ammonia and humus. Adeney has shown that humus-like organic matter prepared by him from sludge bears in chemical composition and attitude towards oxidised bodies (such as nitrates) the same relations as do the brown or black colouring matters of peat.

It may be here remarked that Adeney's estimate of a sewage by determination of the amount of oxidation still to be effected in it by gasometric analysis of the volume of O taken from water in which the sewage is fermented, is the most exact and illuminating method yet advanced, and is the method par excellence for chemists to river boards, inasmuch as its direct experimentation on the fluids concerned admits of no appeal. Five years ago the author procured Adeney's apparatus for his laboratory at King's College, and finds that it works exceedingly well.

There is no doubt that these humin bodies, rich in carbon and poor in nitrogen, and which are found in every ripe nitrifying bed, play an important role in conjunction with the nitrifying bacteria.

Nitrifying beds doing poor work may be improved by seeding with humus from other beds working normally. In 1907, Mr. Percy Lloyd, F.C.S., and the author carried out a series of experiments at Kingston-on-Thames Sewage Works on such seeding of beds, and found that the purification was in all cases increased. When reckoned on the nitric N, this increase ranged at different periods from 5 to 30 per cent. ; and when reckoned on the albuminoid NH_3, the increase was 10 to 16 per cent. From these results it would appear that there are conditions in which increased nitrification goes hand in hand with increased ammonia formation, and one must be careful not to dogmatise or draw *a priori* conclusions as to what may or may not take place in the as yet unknown complexities of the sewage bed

Inasmuch as it requires weeks or months to transform dead proteins in the soil into nitric acid, it is useless to conclude that in a filter bed of whatever type wherein the opportunities for nitrification are often no better than, if as good as, that in the soil, masses of particulate nitrogenous matter are dissociated and completely oxidised in the space of a few hours. In the nature of things this cannot be. It is true that the effluent from such a bed is in physical characters very different from the sewage that entered the bed, but it is not true even in the case of the most efficient bed that the matters with which the effluent has parted have been fully or even partially oxidised. Such a bed is the scene of a multitude of physical and chemical operations acting side by side with a multitude of biological operations. Filtration constantly goes on followed by adsorption ; naked eye particles are caught in the meshes of the filtering medium, whilst ultra-microscopic colloidal particles fall out on the surfaces of the same. When for a period filtration and adsorption have ceased it is conceivable that, granted favourable conditions of temperature, etc., and the presence of efficient bacteria, dissociation may rapidly take place ; but it is not conceivable, even under the most favourable conditions, that dissociation can keep pace with the rapidity with which sewage is usually applied to filtering beds, to say nothing of the further and much more lengthy processes of nitrification. The transparent and odourless features of effluents, the effects of filtration and adsorption alone, have too often been mistaken for purification. The bulk of the matters left on the filter remain unchanged for a considerable time. It is possible in five minutes to transform the foulest sewage into a passable effluent by two or three filtrations through animal charcoal ; but the charcoal at the end of a month will still contain undissociated proteins which at the end of a second month will not have reached the stage of nitrification. If Kjeldahl estimations be made of the total nitrogen in the sewage and effluent a large deficit will always be found in the latter. If nitrification had been continuous and complete, as is so often claimed, the N would have been equal in the two cases. Denitrification does not account for the difference, as it can be shown by a third Kjeldahl operation on the contents of the filter that the N deficit remains in the latter. By careful filtrations and Kjeldahl operations on filtrates and contents of filters one can at any stage of dissociation determine exactly how much nitrogen has gone into solution and how much remains in particulate form ; and this is the only method known to the author of exactly determining the rate of proteolytic enzymic action in connection with sewage work. The determination of nitrification effects is a matter of much more complexity. Anabolic and katabolic activities in low forms of vegetable life apart from bacteria, as also in low forms of animal life found in filters, account for quantities of C, H, N, and S, but only for a time, as these organisms ultimately perish and deliver up the elements to the final equilibrium. How much denitrification with liberation of free N occurs in modern filters it is impossible to say—perhaps more than is generally admitted ; but no filter, even after the largest allowance is made for the escape of free N, approaches anything like a perfect nitrifying machine. Failure in this respect is stamped on all. Where O is admitted most freely, as in sprinklers, the largest amount of nitrates is formed, but large nitrate figures alone do not constitute a good effluent ; there may still be sufficient nitrogenous matter in an early stage of dissociation to enable pathogenic bacteria to flourish. Further, if there be in a filter at any moment much easily oxidisable matter, the admission of the largest possible amount of O will not effect oxidation of undissociated bodies, while the more easily oxidisable matter remains to be served. Moreover, the nitrates which appear in the effluent from such a filter to-day may have been formed in that filter a month ago and are now merely washed out. In phasic enzymic action where it is desired to maintain activity continuously it is important that the products of the end reactions be removed as rapidly as they are formed, otherwise the equilibrium point must sooner or later be reached, and the date at which it is reached will depend mainly on the rate of their removal. This is the rock on which all artificial filters split, some sooner, some later. In the natural purification of sewage on land, nitrates and carbon dioxide are removed by plants, and the equilibrium point is thus continuously set forward. Again, under natural conditions sewage is not constantly entering the soil, so that time is allowed for the execution of the activities of each phase—in other words, the particular energy-transformers engaged are not overworked. The sick sewage bed is like the sick man who overeats—the energy required for the maintenance of the various activities of his body is all used up in a vain attempt to digest and assimilate a continuously increasing quantity of food.

In anaerobic tanks certain foul-smelling gases are needlessly set free. In the presence of oxygen entirely different types of cleavage products are formed whose sulphur is ultimately oxidised in the most unobjectionable manner. All septic tanks as yet constructed deposit sludge. There is no necessity to use noxious methods of protein cleavage when innocuous methods are at hand. The aerobic method of treating sewage has the best of it all the way round. It is possible to construct a septic tank installation on a small scale where all may go well for a number of years—the author has elsewhere reported on such an installation—but large installations without exception fail. The time required for these to reach the equilibrium point is only a detail.

It must be apparent to every intelligent mind that in order to direct a scheme of sewage purification the expert must grasp intelligently the nature of the changes taking place at many points in the cycle, appreciate the conditions which make for continuous action throughout, and when the machine breaks down be able to discover the point of failure and correct it. To this end he must have made considerable progress as a thoughtful and conscientious student in the practical fields of biological chemistry. And as each district and the characters of its sewage must of necessity differ, and differ sometimes very considerably, from all others, he must be able to see that his case is not to be regarded in the light of requiring new methods, so much as needing only a rearrangement of the old. Such a student will perceive at a glance the meaning of the danger inherent in a clear water which later becomes turbid, will comprehend fully the reason why water supplies diffuse the B. typhosus, etc., with a completeness which is almost inconceivable, and why lack of pumping of subsoil water in towns tends to retain these organisms. He will understand that time is the most important factor of all, and that in this, as in every activity related to human life, undue haste is fatal.

Two questions now naturally arise, what is a safe sewage effluent, and how it is to be produced? The members of the Royal Commission on Sewage Disposal, at present sitting, have been discussing these questions for eleven years: the author may be pardoned if, like these gentlemen, he hesitates to make a categorical reply. No standard will ever be possible for all cases; each effluent must be produced with direct reference to the conditions of its district. The local conditions will ever require the most careful consideration. If higher standards be adopted for effluents passing into rivers from which drinking water is later taken, no undue laxity must be allowed in cases where there remains a possibility of intercommunication, by groundwater, by overflow, or by other means, of non-potable rivers or streams with household water supplies. So far as the aquatic life of rivers and the question of nuisance in rivers, in estuaries and on sea fronts are concerned, the application of Adeney's rate and amount of dissolved O test individually to each case appears to be sound. Into streams from which drinking water is drawn, no effluent which contains bacteria capable of producing disease should be allowed to enter. This leads to the vexed problem of determining whether or not an effluent contains such organisms. In the case of B. typhosus negative bacteriological evidence is unsafe. The time that this organism may live and retain its virulence even in pure water is a factor of considerable variation ranging from a few days in some cases to several weeks in others.

There is an element of danger connected with any standard formula for effluents constructed on numbers per c.c. of micro-organisms associated directly or indirectly with disease. In the uncertainty which in the nature of things necessarily accompanies the bacteriology of the subject the safe position seems to be to reject all water for potable purposes into which effluents from domestic sewage are allowed to enter; or if such waters must be used, to raise the bacteriological standard by sedimentation, filtration, etc., of the final product to such a level that all disease-producing bacteria are excluded with certainty. And amongst such excluded bacteria it will be well to number the sporing forms that produce alkaline putrefaction in the lower segment of the human intestine.

Bacterial activity is by no means the only activity engaged in the purification of sewage. Oxidations and reductions are effected by various inorganic compounds. In trade sewages much difference in chemical composition exists; accordingly each sewage should be treated on its own merits and in accordance with the indications of a careful preliminary qualitative and quantitative investigation of its constituents. There cannot be the least doubt that organic compounds in sewage are capable of interacting both in the direction of oxidation and reduction apart from the influences of bacteria; and future work must necessarily assign important functions to some of these. Further, sewage carries enzymes of animal and higher vegetable cells. It has not been possible in the past to separate such from the enzymes produced by bacteria ; hence the erroneous conclusion that has been drawn in certain quarters that all the changes are due to bacteria. It is only necessary to cite one example to show the inaccuracy of this position. Nitrites are converted into nitrates in the presence of O apart from bacteria. Bacterial enzymes as catalysts do not necessarily always, possibly never, initiate reactions of oxidation or reduction, nitrification or synthesis ; they only hasten such reactions.

We know that according to the inorganic and organic constituents of waters and sewage B. typhosus and other pathogenic bacteria disappear in different cases after very different periods of time ; we do not know, however, how long any of these may live and retain virulent functions in the best effluents produced ; we only assume that when a sewage is purified pathogenic bacteria have been destroyed. In most cases such an assumption may be safe ; on the other hand, in certain cases it may not be safe. In the light of present knowledge it would seem that biological chemistry now affords sufficient machinery in the form of methods to carry many problems of sewage purification several steps nearer solution ; such as the determination of (1) the action on bacteria of intermediate and late products of dissociation of proteins, (2) the origin and methods of isolation of those enzymes which most rapidly and completely disintegrate proteins, carbohydrates, and fats, (3) the amount of adsorption effected by different types of filtering material encountering different types of sewage, (4) the concentration of the substrate in the filtering medium which admits of the greatest enzymic change, (5) the influence of temperature on the dissociation and nitrifying processes, (6) the duration in point of time of both sets of processes and of their individual phases, and (7) the exact chemical and physical conditions which sustain the life and produce the death of the pathogenic bacteria of sewage and of sewage effluents. Here is work for another Sewage Commission.

It must be admitted that unwarranted assumption has in the past too largely taken the place of accurate work ; in the future conclusions will be drawn only from the results of the most exact methods of biological chemistry.

Dr. Cresswell Burrows has shown in the author's laboratory that B. typhosus flourishes in 0.5 per cent. solutions of glycocoll and alanin—secondary products of protein cleavage ; and that whilst under certain conditions the organism does not grow at once, it invariably grows if sufficient time be allowed it to overcome the initial inhibition. This worker has also shown that the same organism grows vigorously in 0.5 per cent. ammonia.

Dr. H. J. Cates, another research worker in the same laboratory, has shown that B. typhosus and B. coli survive and multiply in 1 per cent. solutions of asparigin and other amino-acids.

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DISCUSSION.

The President said that the paper was a highly technical one, and he had asked the author to give the meeting a resumé of it in a rather more popular form than it appeared in print. The subject was one for the specialist, and it could not be expected that many of the members of a Society which embraced all classes of engineers would be *au fait* with it. He had great pleasure in proposing a vote of thanks to the author for writing the paper and for the summary which he had given. The paper showed that there was still room for more work to be done with regard to sewage purification, as the author had told them that even to-day it was almost impossible to say when an effluent was innocuous. He appeared to have rather strong views with regard to septic treatment of sewage, and to regard the septic step as undesirable. That was one of the questions upon which engineers wanted to have the guidance of bacteriologists and chemists. These gentlemen could work in their laboratories on sewage problems in a more exact way than could be followed in practical work, and their labours would guide engineers in designing works for carrying out processes of purification. The desirability of having a septic or putrefactive step in the purification process was one worthy of discussion. He could not help thinking that the author's recommendation to avoid taking a water supply from any stream into which sewage effluent was allowed to flow was a counsel of perfection, and that it must be taken with the proverbial grain of salt. Surely the question must depend to some extent upon the amount of sewage flowing in and the degree of dilution, and also upon the distance between the point at which the effluent found access to the stream, and the point at which the water was taken for the supply, or in other words the distance over which natural purifying influences could operate. The author gave an excellent piece of advice in saying that, if engineers must take water which had been polluted more or less with sewage, the water should have been subjected to some process which would with certainty remove all the pathogenic bacteria ; but this was a " large order." He was not quite sure that the bacteriologists could tell them when they had got rid of all the bacteria, and they had not yet indicated the lines upon which engineers could proceed to effect complete sterilization within practical limits of cost. This was a subject which engineers needed to consider carefully before they committed themselves to anything.

The following communication was read by the Secretary :—

Dr. Gilbert J. Fowler wrote that it could be too often pointed out that while the art of sewage purification had made great progress in recent years our scientific knowledge of the underlying phenomena was still extremely fragmentary. This arose from the great difficulty of separating the various factors in the problem, and submitting them individually to investigation. Until this was done it would not be possible to design and operate sewage works with the same certainty of efficiency and economy as was attainable, e.g., in the case of a brewery.

With reference to the statement in the paper that from 16 to 61 per cent. of nitrogen had been found in the gases from septic tanks, he (Dr. Fowler) had been unable, as the result of a very large number of analyses under varying conditions, to find that any appreciable quantity of nitrogen was actually evolved during the anaerobic fermentation of nitrogenous matter. If nitrates were present nitrogen might be obtained by reduction. He was inclined to think that the percentages quoted by Dr. Sommerville arose from the air originally dissolved in the liquid. This, at any rate, was an instance of a fundamental point of considerable importance where a conflict of evidence existed.

Dr. S. Rideal said he thought that the Society would take exception to the statement at the bottom of the first page, that sewage purification was from first to last " a matter of biological chemistry committed to the mechanical devices of the engineer." In the first place, the paper was almost entirely theoretical, dealing only with the chemistry and bacteriology of sewage purification, and did not profess to discuss the engineering details, but they must all admit that the biological chemistry involved was only a branch of the subject of sewage disposal, and that the disposal of the water and of the solids of sewage was after all the work of the engineer ; he contended that the mechanics of the problem were even more important than the theories of the chemist and the bacteriologist. For instance, the flow of the liquid itself was an engineering question which Dr. Sommerville and he (Dr. Rideal) as chemists knew nothing at all about. Whatever the chemico-bacterial changes in tanks which determine the precipitation of the solids, the mechanics of the removal of solids from a liquid was really the most important part of the whole problem. He ventured to think sewage disposal could be carried out by the engineer without his considering in detail the chemical and bacteriological changes which were taking place, as the removal of the liquid or of the solids from one place to another were simple problems in hydraulics and mechanics.

The author had stated that the recent work on colloids had not been applied to the problem in practice to any great extent. Let them look at what was meant by a colloid. It was a substance which was so small that it could only be seen by means of an ultra-microscope, and, being so small, its surface was very large in relation to its mass, and it had physical properties which were different from those of larger substances. This, as his friend Dr. Travis would urge, had a very important bearing on the sewage problem. That was not chemistry nor was it biology, and yet Dr. Sommerville wished them to look upon the subject as one of pure chemistry and bacteriology.

A very interesting and important definition of what was meant by a pathogenic organism was also given by Dr. Sommerville, and he (Dr. Rideal) took it that what the author wished them to gather was that, in future, they must not speak of the bacillus coli communis, or the group of organisms which were associated with that particular name as being non-pathogenic, and when found in waters as only an index of sewage pollution, or that where that went organisms like those of typhoid and cholera might follow, but that they must look upon these groups of organisms and all those which came out of the intestines as being pathogenic, because they could produce gas and thus cause distension and discomfort, and so productive of disease. If this was what Dr. Sommerville had in his mind, the same argument could be applied to particles of glass, as it might be said that particles of glass in water had pathogenic properties because they were capable of causing some condition that might eventually cause death. Dr. Sommerville wished them to extend the list of dangerous organisms and thus make the question of what was meant by pure water or by the purification of a sewage effluent far more complicated than it had been in the past.

The author discussed the hydrolysis changes of proteins and carbo-hydrates. He did not know why he said that the carbohydrate change was a more rapid change than the protein change. He (the speaker) should have thought that if they had some sugar in water in one tank and some albumen in another tank, and they each had the proper enzyme, the different kinds of sugar would ferment at different rates, and that the albumen would break down into albumose and peptone at a rate depending on the food supply and the kind of enzyme that was presented to it. These velocities would necessarily be different, but the author generalised, and said that the first thing that happened in sewage was the breaking down of the sugar, and the next thing the breaking down of the protein ; and the last thing, which if present in large amounts would not break down at all under any natural process, was the cellulose. As far as he had read, there was no ground for this statement, and he did not know why the author had ventured to put forward such a statement.

With regard to ammonia and secondary decomposition products, were they to regard ammonia as a primary product or a secondary product ? The author said, " With a few exceptions all the primary dissociation products of albumen are α-amino acids of the general configuration " and so on ; whereas, somewhere else in the paper he pointed out that ammonia could be broken off in the preliminary change and also in the secondary change. The use of the terms primary products and secondary products was a little confusing. The secondary ammonia product had very little resemblance to the original protein from which it was derived. The statement needed a little revision to make it clear.

The sequence of changes was a thing for which some chemists had long contended. Although the change took place in a septic tank or a contact bed in a very confused way, there was no doubt that it was very gradual. Mr. Moncrieff many years ago at Caterham had built a filter in trays, and he had traced for him the changes in such a filter by examining the quality of the effluent from tray to tray. He found that the nitrogen was first of all converted into ammonia, and then into nitrite, and then into nitrate in sequence. Dr. Sommerville used the word "nitrification" as applying to a conversion of ammonia into nitrites. He (Dr. Rideal) thought that the word "nitrosification" was adopted usually to indicate the first change, the oxidation of ammonia into nitrite. Nitrification was the whole phenomenon, and should, perhaps, be restricted to the conversion of the nitrites into nitrates. It certainly was not the right word to use for the conversion of ammonia into nitrites.

The President, in his opening remarks, had summarised very well the practical applications to be drawn from the paper. Dr. Sommerville's main conclusions were that the septic tank was a failure and that effluents must not be allowed to flow into drinking water. But neither of those statements was borne out by the theoretical considerations which were mentioned in the early part of the paper. With regard to the septic tank, the author clearly showed that the breaking down of the organic substances by means of enzymes was accompanied by the evolution of gas, and that gas was a necessary product of the preliminary change. Carbonic acid was evolved in the breaking down of the carbohydrates and ammonia in the case of protein. Therefore, whether these changes took place in a contact bed or in a septic tank, gases were produced. These gases were not offensive. Nor were hydrogen and marsh gas produced in cellulosic fermentation, and the production of sulphur compounds was not dealt with in the paper. He (Dr. Rideal) thought the paper had clearly shown that to bring about the decomposition of solids in sewage they must have an anaerobic preliminary, the breaking down of which had nothing to do with the oxygen in the air. When there was not this anaerobic preliminary the solids could be deposited on slates, for example, until a worm or a bird picked up the solid and took it somewhere else. They could also get rid of the anaerobic preliminary by having a centrifugal machine, and whirling the solids away, as was done at the new works at

Frankfort and Hanover. But these alternatives had nothing to do with the paper.

With regard to the quality of the effluent, the author said: "In the uncertainty which in the nature of things necessarily accompanies the bacteriology of the subject, the safe position seems to be to reject all water for potable purposes into which effluents from domestic sewage are allowed to enter; or, if such waters must be used, to raise the bacteriological standard by sedimentation, filtration, etc., of the final product to such a level that all disease-producing bacteria are excluded with certainty." Sedimentation for purifying sewage was a question of mechanics. Filtration was also a question of mechanics, so he supposed that the "etc." was sterilisation, which was a problem for the electrician. In the wording of Sec. 17 of the Public Health Act, instead of "under no circumstances should there be discharged into any watercourse or stream any sewage effluent containing excrementitious or other foul or noxious matter which was harmful to the river," the author would substitute "any pathogenic organisms, including many which we had never been accustomed to call by that name." He congratulated the author on having read a very interesting and suggestive paper on the subject.

Dr. Owen Travis said that he would like to compliment Dr. Sommerville upon his very able paper. He agreed as to the pressing necessity for research, and believed that what was wanted to elucidate the subject of sewage purification was prolonged practical experiments conducted upon sewage at sewage works. He had been engaged daily and hourly during the last six years in such experiments. He had watched the deposition of sewage, the coagulation of its colloidal contents, and the absorption changes upon the material in tanks and filters, the sides of which were of glass; had confirmed these results by experimental investigations; and had demonstrated their applicability to practical operation. The question of how a foul sewage was converted into a clear effluent was the crux of the problem for the engineer. When he started the experiments, it was assumed that sewage which came into and passed through the works was converted into a sparkling effluent by the bacteria, and the operation was called the bacterial purification of sewage. When other life was seen to be present, and it was shown that bacterial action could not account for the entire sequence of changes—it was called a biological process. Now, however, it was found that, instead of the change being a bacterial one, or a biological one within the narrow limit of the biologist, it embraced the vital operations of a wide range of animals and plants. He had found it to be necessary to distinguish between the physical and the vital operations, between the physico-chemical and the bio-chemical effects. The conclusion that he had come to had been very largely brought out in Dr. Sommerville's paper. The sewage in passing through the sewage works was completely deprived of its impurities in virtue of the mechanism which the engineer had designed and installed, whether it was a septic or other tank, a contact bed, or a percolating filter. The mechanism had taken out the impurities, and these remained behind in the treatment area, there to be dealt with not by bacteria only or by their enzymes, but by the whole range of life contained in the area. The life that he referred to included birds, insects, worms, etc. One noted zoologist had said that flies flew away with the bulk of the sewage ; that would appear to be a very extreme statement, but not more so than that which would attribute the whole result to bacterial action. He (Dr. Travis) had determined that the primary effect in sewage work was a physical de-solution, and that the vital effect was consecutive and subservient to the physical operation. These findings were brought out in a very clear way in Dr. Sommerville's paper, where he showed that the transparent and odourless features of effluents were the effects of filtration and adsorption alone, and that these results had too often been mistaken for bacterial purification. The whole question hinged upon what was meant by purification. If it were believed that purification was only effected when the whole of the impurities were destroyed, then surely all must agree with Dr. Sommerville that "sewage purification is from first to last a matter of biological chemistry," but these results were not completed in the treatment area, and the products would have to be followed to the land, river, and sea. If, however, the purification of the sewage was understood to occur within the limits of a treatment area, and the effect to be limited to the operations of that area, then the physical action was dominant, and was evidenced by the huge accumulations to be found there. He had great pleasure, so far as he personally was concerned, in recording his appreciation of Dr. Sommerville's paper.

Mr. S. R. Lowcock said that the great advantage of such papers as that under discussion arose from the fact that engineers had to rely upon the chemist and the bacteriologist to tell them what to do, or rather what the process ought to be for which they had to construct works, and papers of this kind were exceedingly useful in that respect. There was a considerable difference of opinion as to the lines upon which they should proceed, and that difference had been emphasised that night. There were one or two points on which he quite agreed with Dr. Sommerville. The thing in which he agreed with him most, perhaps, not only from theoretical consideration, but from his practical experience, was the following statement : "It is possible to construct a septic tank installation on a small scale where all may go well for a number of years, but large installations without exception fail.

The time required for these to reach the equilibrium point is only a detail." His experience was that a septic tank was a perfect nuisance and a mistake from beginning to end. They could not prevent all fermentation. Urea and uric acid broke up far more quickly than they could possibly be got away from the liquid. But he was perfectly convinced that what they had to do was to get the solids away from the liquids as quickly and entirely as possible and to prevent putrefaction. In that he entirely supported Dr. Sommerville's views. The liquid should be dealt with subsequently. They had to deal with the solids as well, and that was the great difficulty at the present time. If the chemists or bacteriologists could indicate the lines on which they should proceed to effect the satisfactory and economical disposal of the solids, they would confer a great practical benefit. He did not think that the liquid presented any great difficulty if the suspended matter was removed and the filters were properly designed and worked, but if they tried to break down the solids in the liquids in the tank, and sent them over on to the filters in a state of fine suspension they would clog up the filters. The practical position was this : Either they must separate the solids in the tanks and deal with them separately, or take out and wash the material forming the filter beds.

Mr. H. C. H. Shenton said that the paper being a purely chemical one made it difficult for an engineer to discuss. It was not very satisfactory for engineers to receive from an eminent chemist and bacteriologist the statement that it was almost impossible to tell when an effluent was pure. The author practically stated that whatever method of purification was used —whether filters or contact beds or what not—one must never expect to have an effluent fit to be discharged into a river, which was the place where most effluents had to go. Dr. Rideal had said that this fact showed that authorities must sterilise, which they were not likely to do except in extreme cases. One speaker had remarked that it was impracticable to sterilise water or to remove pathogenic germs on a large scale ; but he (Mr. Shenton) could recall the instance of New Jersey in the United States, at which place water was being sterilised on a large scale, at the cost of sevenpence per million gallons, and there were many other cases in which sterilisation was being practically accomplished.

Mr. A. J. Martin said that there was a disposition in some quarters, though he did not impute it to Dr. Sommerville, to define an engineer as a sort of lower animal utterly ignorant of chemistry. He admitted, however, that it was not an easy thing for an engineer who had his living to earn to keep fully in touch with all the ramifications of organic chemistry. A paper like the present one was therefore to be welcomed, and they were all indebted to the author for the extreme lucidity with which he had placed before them the suc cession of changes which took place in the decomposition of protein. He had made the subject very clear by his use of formula, and by his statement that the products of the first decomposition retained their carbon chain intact, and their nitrogen unchanged. In one place he told them that there was no necessity to use noxious methods of protein cleavage when innocuous methods were at hand. His use of the word " noxious " seemed to be somewhat arbitrary, and in any case it pointed to a curious revulsion of feeling. Some years ago the chemists who were chiefly looked to as authorities on matters of sewage disposal were practically agreed that the first stages of the purification of sewage were preferably,if not necessarily, anaerobic. Since then there had been a complete swing of the pendulum. The Royal Commission on Sewage Disposal stated in their fifth report that the effluent from a septic tank was not only not more amenable to filtration than that obtained by chemical precipitation, but was actually less so. One gathered from reading the report that that opinion was based partly on considerations connected with the dissolved constituents of the effluent, but largely on the question of the amount of suspended matter which it contained. The Local Government Board seemed disposed to go further, and to take up the position that, no matter how completely the suspended solids might be removed from a septic tank effluent, twice as much filtering material must be provided to deal with a certain quantity of that effluent as for an effluent obtained by chemical precipitation. When they found an opinion of that kind held by the Royal Commission and by Dr. Sommerville on the one hand, and the contrary view expressed by such men as Dr. Angus Smith and Dr. Rideal, and by Professors Marshall Ward, Frankland, and Sims Woodhead, one could not help thinking that the whole truth was neither on the one side nor on the other, but somewhere between the two.

The author had described the chain of processes by which protein was broken down into inorganic constituents ; but from a consideration of all those processes it would hardly seem that they were distinctively aerobic. It would appear that some at least of them were capable of taking place under anaerobic conditions. He would like to ask at what stage the anaerobic processes could be said to have been carried too far and the foul-smelling gases to begin to be evolved. For practical purposes, in the designing of purification works, if anaerobic tanks were provided, they were cut up into a large number of units, so that it was not necessary to use at one time more than were required for the separation of the solids from the liquid. If this were done, it ought to be quite possible to arrest the anaerobic changes at a point antecedent to that at which foul-smelling gases were produced.

He wished to ask one question with regard to humus. He noticed on a recent occasion, when a paper by a distinguished chemist was under discussion, a disposition to restrict the term "humus" to the solid residuum produced by a particular process, and to deny it to that yielded by other processes. The report of the Royal Commission showed that it was possible to obtain in a septic tank a residuum containing an exceedingly small proportion of organic matter, and that in a condition in which it did not undergo further decomposition. Was the word "humus" rightly applied to material of that kind?

He joined with the author very heartily in his deprecation of a fixed standard, but he noticed a disposition on his part to lay down a standard to which he (Mr. Martin) should strongly object. He seemed to think that the effluent from a sewage works could not be considered satisfactory unless the last pathogenic organism was killed. He (Mr. Martin) would regard it as a great misfortune if the effluent from sewage purification works were generally turned out in such a condition that it was looked upon as safe to take the water into which the effluent was discharged and use it for drinking purposes. He thought that they must interpose a further line of defence between the consumer of the water and the sewage effluent; and to do that was, he conceived, the duty of the water authority.

The author had spoken of the great complexity of the sewage problem, and had argued from this that it was a question for the chemist rather than for the engineer. He did not think that the author was quite on sound ground in that respect. If it were a simple chemical problem, no doubt it would be one for the chemist, but its very complexity took it out of the domain of exact science. The mere laboratory chemist would come to grief in dealing with the sewage problem. Both the practical knowledge of the engineer and the scientific knowledge of the chemist should be brought to bear upon the question, and then there would be a fair prospect of getting satisfactory results.

Mr. J. Custance said he was a sewage works manager, and dealt daily with volumes of sewage. He knew little of chemistry, but from practical experience a man got to know the behaviour of sewage and the result likely to be obtained by certain treatment. If everything could be done as the chemist said it could, how was it they did not get some design which would solve the sewage problem? He believed that in the final solution of the problem they would find the engineer and works manager working together, and the chemist would come in to examine the results.

REPLY.

Dr. Sommerville said that, despite the caustic criticism of his good friend Dr. Rideal, he held tenaciously to the necessity for the knowledge of principles which he had advocated in the paper.

If Dr. Rideal read page 183 he would find it stated that "cellulose is practically the only resisting substance, and where it occurs in large quantities it should be treated by artificial hydrolysis." When the author penned these words he had in his mind one case in America where the cellulose in sewage from a paper mill could not be hydrolysed in septic tanks nor in contact beds, and had to be hydrolysed artificially; and two similar cases on the Continent of Europe.

A pathogenic organism was an organism capable of producing disease. That the B. putrificus and other sporing organisms found in the lower bowel were able to set up chronic toxic conditions in man had been demonstrated by several workers in Europe and by Herter in America.

He could not understand Dr. Rideal quarrelling with the statement that carbohydrates were oxidised more easily than proteins. The oxidation of carbohydrates required less expenditure of chemical energy than did that of proteins. It was a mistake to suppose that under every condition some of the dissociation products of proteins were easily oxidised.

The ammonia split off in the early stages of the dissociation might be accompanied by living pathogenic bacteria; that split off in the late stage might be free from such bacteria.

In septic tanks, in addition to protein cleavage, there was a splitting off of sulphur compounds of different composition and characters from those formed under aerobic action He was obliged to Dr. Travis for his appreciation of the paper. He was sorry that he did not know Dr. Travis's work; but regarded his remarks as sound.

As to when an effluent was safe, it was in the nature of things impossible to say; and he was content to remain an agnostic until more was definitely known of the bacteriology of the subject.

As regards humus, he had given a table from a reliable German paper in which was shown the ratio of nitrification in the presence of humus to that in its absence; as cited, this work had been confirmed by Mr. Lloyd and himself, at Kingston.

NOVEMBER 27TH. 1909.

MEETING AT LEEDS.

VISITS TO WORKS.

THE only provincial meeting of this session was held at Leeds on Saturday, November 27th, 1909. All the arrangements were made through the kind offices of the President, Mr. E. J. Silcock, M.Inst.C.E., who practises as a consulting engineer in that town as well as in Westminster, and is therefore well known in the locality.

The attendance was not as large as might have been anticipated, but those who were present had the privilege of visiting one of the largest engineering works in Leeds, and the site of an important street improvement now being carried out by the City Corporation, in addition to having the opportunity of discussing the valuable paper read in the afternoon and fully reported on another page.

The party assembled at the Hotel Metropole, King Street, at 10.15 a.m., and thence proceeded to

MESSRS. GREENWOOD & BATLEY'S ENGINEERING WORKS.

Cloth making has for many years been the staple trade of Leeds, but of late the engineering industry has come very much to the fore as an aid to the prosperity of the city. The firm of Greenwood & Batley was founded in 1856, and at the present day their range of manufactures is very comprehensive, including machine tools, wood-working, oil-mill, textile, and other machinery, dynamos, electric motors, De Laval steam turbines, etc. The works are situated in Armley Road, covering about 10 acres adjoining the Midland Railway and the Leeds and Liverpool Canal, the floor area of the workshops being over 32,000 square yards.

One of the firm's specialities is the manufacture of oil-mill machinery, which is not made to one standard pattern, but is specially adapted in each case to the special class of seed or nut to be treated. In the case of a plant for the treatment of the African palm nut, an automatic arrangement is introduced for separating the kernel from its casing; the former being then conveyed to the rolling mill, after which the mashed kernel is "cooked" and passed into hydraulic presses furnished with a measuring cake-forming appliance so constructed that the oil may run freely through the apertures provided, the residue being left in the chamber in the form of cakes. Other machines are made for crushing linseed, cotton seed, rape, etc., each being designed for the special purpose to which it is intended to be applied.

A department which proved of considerable interest to the visitors was that devoted to the manufacture of De Laval steam turbines, turbine pumps and fans, for which the firm are selling agents in this country and many other parts of the world. The De Laval steam turbine is a Swedish invention, and the most modern portion of Messrs. Greenwood & Batley's works is given to the production of these engines.

Another of the more modern shops is that in which dynamos, electric motors and other electrical apparatus are made. In addition to the manufacturing department the firm have their own plant for electric lighting and power generation ; motors have been provided on each main shaft in the older shops, and in the more recently erected premises practically every new tool is provided with a separate motor.

Among the miscellaneous products of these works may be mentioned improved machinery for the treatment of China grass and waste silk, and testing machines for wire, yarn, cloth, cement, leather, and other substances, besides wood-working machinery, cotton-baling presses, etc. Of course, with their great variety of manufactures, an extensive business is done with foreign countries and the Colonies, and the mere survey of their premises proved most instructive to those who were able to be present.

On leaving Messrs. Greenwood & Batley's works a visit was made, under the guidance of the chief assistant to Mr. W. T. Lancashire, Assoc.M.Inst.C.E. (City Engineer of Leeds), to inspect the

Hope Street Improvement.

This work, now nearing completion, is the second portion of a new thoroughfare, 75ft. wide, which will connect York Road with the centre of the city, at the junction of New Briggate, Vicar Lane, and North Street. It has been decided to give the new street the name of York Road also.

The street is one of several improvements which are being made with a view to opening out an area of some 66 acres, acquired by the Corporation under Part 1 of the Housing of the Working Classes Act, 1890, improving thereby not only the general health of the city by the removal of the worst class of property, but enabling the district to be developed on lines suitable to modern requirements, and to be put to such uses as are most beneficial to the city.

The streets which occupied the site of the new York Road were, generally speaking, about 25 feet in width, and were bounded on both sides very largely by the worst type of back-to-back houses.

The portion which was completed some three years ago is in parts 12 and 13 feet below the level of the old roadway, the original ground level being some 28 feet above the present level. The street at present under construction runs at one gradient from North Street to the junction with the portion already constructed, at which point a circus 200 feet in diameter will be formed. Carrying this street through at one gradient causes the new level to be in places as much as 15 feet above the old level, but there is the advantage of making the gradient much easier for traffic. The new gradient is 1 in 27, whereas the gradients of parts of the street which covered part of the same site were 1 in 17 and 1 in 15.

The properties which front on to the old street are being refronted, and new buildings are being erected fronting on to the new street line. These are owned by private owners, as is all the land on the south side of the street between North Street and the bridge.

The retaining walls are built of 6 to 1 concrete, composed mainly of broken brick (largely from demolished property), sand, and cement, with no reinforcement, except at the causeway level. The back of the retaining wall is battered, and counterforts 6ft. wide occur at intervals of 30ft. centre to centre. A 9in. sewer is laid on the back of each retaining wall, and junctions and pipes for house connections are carried through the wall at intervals of 15ft., access to the sewer being obtained by manholes and lampholes built in the counterforts of the retaining wall at intervals.

A subway 7ft. wide and 6ft. 6in. high is laid from end to end of the street ; under Bridge Street it is divided into two conduits, each 3ft. diameter, and after crossing the beck at the lowest portion of the street it is to be connected to the subways already existing on the other side. This subway is intended for use for through pipes and cables, and not for service pipes and cables, which are to be laid under the causeways. The sides of the subway are built of concrete, supporting a semi-circular brick arch covered with concrete having a waterproof layer 1in. thick on top.

The bridge over Bridge Street is constructed of steel girders and jack arches, with concrete cover floated to receive $\frac{3}{4}$ in. thickness of rock asphalte before the wood paving is laid. The span of the bridge is 42ft., and the steelwork parapets are 75ft. apart. At the present time the street is only 69ft. in width so as to allow the buildings which may be erected on either side to have areas for light in front of the building lines.

The street is being temporarily paved with second-hand Yorkshire paving until consolidated, but will be ultimately paved with wood. The flagging is also temporary.

In order to allow of the construction of the circus at the junction of the completed street and the new one, the beck is to be widened to 20ft. and covered in. A circus with a centre island 70ft. in diameter is necessary in order to deal with the varying levels of Mabgate and Regent Street, which both run into it. Inexpensive iron railings, firmly fixed into the concrete walls, give protection to those who will use the street.

Judging by the nature of the buildings which have already been erected, there appears every reason to believe that this street should prove in the future one of the most imposing thoroughfares in Leeds, and when compared with the squalid streets and courts it replaces, the advantage which the city will gain is obvious.

The capital expenditure up to the present time is about £750,000 on the whole scheme, and the cost of this new east and west street will be about £40,000, exclusive of the value of land.

After having walked over the site of the new road, the party adjourned to the Hotel Metropole, and there luncheon was served.

At 3 p.m. the meeting which is reported below took place in the hotel.

AFTERNOON MEETING.

EDWARD JOHN SILCOCK, President,

in the Chair.

The **President,** in opening the proceedings, remarked that that was the first meeting which the Society of Engineers had held in the Yorkshire district, and he regretted that there was not a larger muster of members. He had hoped that being the first meeting, the members in the neighbourhood would have rallied round in goodly numbers. He supposed that the day did not suit the convenience of everybody who might have been present, and they would have to make up in quality what was lacking in quantity. There was one duty which must be performed before going on to the reading of the paper, and that was to pass a vote of thanks to Messrs. Greenwood & Batley and to Mr. W. T. Lancashire, the City Engineer of Leeds, for their kindness in arranging the visits of that morning. He thought that what they had seen was of great interest, and he was only sorry that there had not been more members present.

The **President** then formally moved that the thanks of the meeting be sent to Messrs. Greenwood & Batley, Ltd., and to Mr. W. T. Lancashire.

Mr. R. W. A. Brewer, seconding the resolution, said that he was sure that all who had been present profited very much by what they had seen, and were very grateful to those who had given them the opportunity of seeing the works they had visited.

The resolution was put, and unanimously carried.

The **President** then called upon Mr. Cornock to read his paper.

STEAM WAGONS.

By J. C. Cornock, A.M.Inst.C.E.

As a preface the author desires to explain that, although connected with a firm of steam wagon makers, he has endeavoured to avoid anything approaching advertisement. Unfortunately it generally happens that an engineer is commercially interested in the branch he knows most about and if this subject is to be avoided one is compelled to attempt a subject on which perhaps the hearers know as much as the writer.

The past history of steam wagons centres largely on Acts of Parliament, and their improvement has been retarded by legislation. If the law had permitted it, makers had enough experience to build reliable machines considerably earlier, but it is only since 1904 that the legal tare limit has given us any chance at all. Seeing that a history of the stages through which these machines have passed would deal so much with these obsolete machines, it is proposed to ignore the early designs and come at once to modern machines.

A few years ago the chief points of dispute were the *type of boiler* to be adopted and the *method of transmission* of the power from the engine to the driving wheels. To-day the two distinct classes are the wagons having the engine beneath the platform and enclosed in an oil bath, and those with an open type of engine carried on top of a locomotive boiler. The locomotive boiler is not peculiar to the latter class so that the real distinction is in the position of the engine, the more so as both classes contain examples of both gear and chain drive.

The " over-type " and the " under-type " engine entered the field at almost the same time in the form of a tipping cart built by the Mann Steam Cart and Wagon Co., of Leeds, and a steam wagon built by the Thornycroft Steam Wagon Co., the modern forms of these two classes being shown in Figs. 1 and 2. The cart is practically a miniature traction engine with the addition of a body over the back wheels, and carries the engine directly on the boiler barrel. The crank shaft is coupled to the driving wheels by spur gearing and one or more intermediate shafts. The wagon in Fig. 2 is not the Thornycroft, as they have discontinued the manufacture, but is a modern representative of the type, and has, as common features with the cart, the locomotive boiler and the gear drive. The great difference is in the engine, which is beneath the platform, and is therefore closed in and self-lubricating. Obviously the length of body on the cart is limited by the length of wheel base which can conveniently be bridged over by the intermediate shafts and gear wheels. In practice and with the present tare weight limit, one can hardly exceed two intermediate shafts, and the diameter of the gearing is limited by questions of road clearance. As a result the over-type gear-driven machine is limited to about a 9ft. body, and for carrying sacks, barrels or any goods needing a long platform either the under-type machine must be adopted or a chain must be introduced into the transmission as shown in Fig 3, which shows the transformation of the short-bodied cart into the long-bodied wagon.

A few years ago the choice between the two types of wagon was a question of chain drive versus gear drive, and many firms adopted the under-type solely to avoid chains, which had not then arrived at their present state of reliability. To-day chains are undoubtedly vastly improved and makers do not fear to use them, so that the point to consider is the relative merit of the two types of engine. It is not a question to which one can give a dogmatic reply and state " This is right and that wrong."

The author's experience is that the self-lubricating engine will do a bigger mileage in a day, which is natural in view of the better conditions in which it works. One would naturally prefer to place any mechanism in a cool bath of oil rather than on top of a hot boiler exposed to dust and dirt, but unfortunately a further factor, the human element, enters in. For success it is essential that the oil bath shall be intelligently used and in this respect it is not only the driver who fails but unfortunately often the owner as well. The chief factors are a proper quantity of suitable oil and a periodical cleaning out and examination of the engine with any necessary adjustment of brasses. If an over-type engine is neglected it soon knocks like a steam hammer, and the neglect makes itself obvious to even a casual observer, so that the driver is almost forced to attend to it. On the other hand, with the engine in a bath, the brasses may be equally slack and hammering equally badly, but the noise is muffled and the neglect may go on to actual breakage. This kind of neglect may be due to the laziness or ignorance of the driver, or to the greed of the owner in refusing time or facilities for adjustment, and frequently it is almost impossible to apportion the blame properly.

The most serious cause of trouble is the use of unsuitable oil, and it is extremely difficult to get either owners or drivers to understand that oil may be good enough as oil, and yet utterly unsuitable for bath oil. Certain grades and mixtures containing heavy cylinder oil become thick and pasty when churned up by the cranks and are then quite unable to penetrate oil-holes, pin joints, etc.

In addition to this the oil sticks to the rods, etc., and as it cannot run off, any grit which may be present adheres to the parts instead of falling to the bottom of the bath. Apart from this too the parts are so coated with thick unpleasant grease that the driver has every excuse for feeling disinclined to tackle the job of cleaning or adjusting, although without cleaning it is quite impossible for him to see whether nuts are loose or any part needs attention. A suitable oil should remain fluid, without getting thin, and should leave the bearings and rods clean and pleasant to touch. It can be bought for about eighteenpence per gallon, and yet, although the fact is persistently pointed out, a large number of users will not take advice.

It will thus be seen that the points against the oil bath are not defects in the oil-bath principle, but lie in the shortcomings of those using it. Personally the author advocates the use of an oil bath, for when it is properly used the extra mileage of the self-lubricating engine is well worth considering. For the man who cannot or will not trouble about proper treatment it is at least debatable which type to advise. In many ways it would be well if a steam wagon could lie down and die under persistent ill-treatment like our old friend the horse.

Coming to details of the machines the first feature to consider is the frame. In the over-type wagons the boiler always forms an essential part of the frame, and also forms the foundation of the engine, while generally also carrying the intermediate shafts and gearing. In the under-type the engine and boiler are units distinct from the frame and therefore the frame is more flexible and more elastic in its action on the road. In both types, whether with the rigid or flexible frame, it is essential to avoid sudden changes of section, or any deflection is sure to be localised at this point with risk of breakage. A frame should be either completely rigid (a condition difficult to obtain if the frame has to be of any length) against both vertical and side strains, or it should be uniformly flexible.

The cart in Fig. 1 shows an example of a rigid frame, the boiler sides being carried back and strongly braced together to carry the shafts and body. The frame section tapers towards the back end and is strongest about midway between the back and front axles. The under-type wagon, Fig. 2, illustrates the flexible type of frame. As used by most makers who build this type it is formed of plain channel section steel girders, joined by cross girders which both brace the main girders and carry the mechanism. Fig. 4, however, shows a type of frame built by the Mann Steam Cart and Wagon Co., and which is considered far more scientific than a uniform section as giving a more uniform deflection and less chance of local strains. The actual stresses in a frame when running with a load on an uneven road are absolutely indeterminate and therefore the method adopted in designing this frame was to proportion the width of the flanges to the proportionate bending moments at different points on the frame, taking these at the attachments of the springs, centre of engine, boiler, etc. These bending moments were calculated with different systems of loading, and with tanks both empty and full. The basis channel section was chosen as a reasonable one by past experience (a calculation of actual stress being quite impossible), and assuming this for the point of minimum bending moment it was then a simple matter to proportion the width of the reinforcing plates to the varying bending moments. Of course the actual stresses are not caused by pure bending, but as a frame has never yet been broken, the method was not far wrong.

The over-type engine (Fig. 3) shows a frame which comes between the previous two types. It is not flexible, neither is it absolutely rigid, but the change of section is made gradual by tapering the horn plates from the rigid portion formed by the boiler so that they gradually reduce to the section of the steel channels forming the rear extension. If the channels were only attached to these tapering extensions of the fire-box side plates there would be a lack of lateral stiffness and all the side strains would be localised at the end of the rigid fire-box, with inevitable cracking of the horn plates. This is prevented by carrying the channels to the front of the fire-box, bolting them by driving-fit bolts to the horn plates and also to substantial planed steel angle brackets riveted to the boiler shell side plates. None of these bolts enters the steam space, so that there is no risk of leakage. In some designs of over-type wagons, as built by Messrs. Fodens, Ltd., Wallis & Steevens, Ltd., and others, these channels are carried forward to the smoke-box and attached to it, in which case the back of the boiler merely rests on the frame and the horn plates are only extended to carry the intermediate shafts, and are not tapered down to the channels.

The next item is the boiler, and the controversy of a few years ago as to type is practically over, the majority of makers now using the locomotive, although the Yorkshire Steam Wagon Co. still use a double-ended locomotive boiler placed across the front of the wagon, and Leyland Motors, Ltd., still use the vertical fire-tube type. On the introduction of the steam wagon there was a revival of the old fear of trouble on hills from the fire-box top or tube ends being laid bare of water, but experience has quite borne out the experience of traction engine makers long ago, that this trouble is really non-existent. Apart from any other factor the water in a road engine is in a state of very violent motion and no part can possibly remain dry for more than a small fraction of a second. Granted this, the simplicity of the locomotive boiler very strongly recommends it.

As regards the engine there are bigger differences in practice, except in the case of the over-type wagons. For these an engine with its cylinder bolted to the boiler barrel and its crank shaft carried on the extended sides of the fire-box is universal, and the engine is not placed in a bath. The bath is not necessary as the mechanism is always beneath the driver's eye, but apart from this the situation is of necessity a hot one and the temperature is bound to rise considerably if the engine is running in a closed chamber of heated oil.

For the under-type wagon it is usual to carry the engine and its oil bath as a self-contained unit slung from the frame by trunnion bolts so that it can remain truly in line even though the more-or-less flexible frame is twisted by its heavy load on an uneven road. The majority of engines have flat slide valves, but a few have piston valves, and one wagon, the Sentinel, has lift valves driven by cams on a layshaft. The arrangement is very similar to that of a gas engine and permits a very early cut-off; a point of importance in this case, as the engine is not compound but has two high-pressure cylinders. With this exception all wagons have compound engines, and usually a by-pass is provided to admit live steam to the low-pressure cylinder, for starting if the high-pressure crank is on a dead centre.

A departure from the usual practice which should be mentioned here is the engine of the Yorkshire Steam Wagon Co., which has a vertical compound engine placed on the footplate beside the driver. In classification this wagon must be placed with the "under-type" owing to the style of its frame and the fact that the engine is not on top of the boiler, although the engine position allows the use of a long chain, which is a factor of importance, and the arrangement fits in well with their design of boiler.

A necessary feature to watch is ready accessibility of the engine even with a load on the platform, and preference should be given to an engine with the whole top of the bath removable, rather than one with inspection doors only. With a little care in design the parts can be arranged so that even a crank shaft can be replaced without unloading.

Having discussed the engine and boiler the next question is transmitting the power to the road wheels, and on this point there is still controversy on the merits of spur gearing or chain drive. A few years ago the author would have strongly advocated the gear drive for heavy machines, say those carrying five or more tons, but chains to-day possess properties of quality of materials and workmanship to which little exception can be taken. To-day therefore, either a gear drive or a chain drive may be considered satisfactory if equally well carried out although the chain drive is heavier.

To get satisfactory life, the longer the chain the better, and the long chain on the overtype wagon weighs about 2 cwt. To set against this there is no saving in weight of gear wheels, as exactly the same number of pinions and wheels is required, the last pair being merely coupled by the chain instead of gearing into one another. It is generally considered that the chain drive is quieter than the gear, but each can be very noisy when worn, and a properly made gear drive is certainly not noisy. Even with a chain for the final drive the crank and intermediate shafts must have spur wheels to save length and allow two speeds to be fitted. The chain drive has what is perhaps a good feature—that to be even possible it must be a good job—and very often it has been compared with gear drives which were badly carried out and noisy but which still worked well and cheaply. The old fear of a broken chain on a hill is not so much to the fore, but no doubt the consequence of a broken chain is more likely to be a run-away, as if a tooth breaks in a gear-wheel it may run for miles in safety, or if the tooth jams, the effect is to lock everything and bring the machine to a standstill.

It might be as well to refer to a variation of the single chain drive in which the single chain is replaced by two running side by side, the teeth of the gear wheels being divided on their centre line to admit the side links of the chains. The idea is that if one chain breaks the other will be strong enough to get home with, although not strong enough for continual work. At first glance it seems rather a good idea, but unfortunately the broken chain develops a bad habit of falling across the remaining one and tangling up with it so that the resulting smash is pretty considerable.

With either the single chain or the gear drive the differential is on the back axle, which is of the live pattern, and it is invariably of the bevel pinion type. The differential with parallel spur pinions is not employed by any steam wagon maker.

On several of the earlier wagons and on one modern pattern, the Leyland, the differential is on the intermediate shaft and is placed inside the engine oil bath. It is of course much smaller and more compact, being on a quick-running shaft, and the final drive is by two chains, one to each road wheel. With this arrangement the back axle is fixed and the road wheels revolve on it.

The best results have been obtained by running the main gearing uncovered as, if properly oiled, any dirt which may splash on to it promptly drops off without causing trouble. At first sight this seems primitive but the facts justify it. The range of load on the wagon springs is very wide, and the amount of axle movement makes a dust-proof casing very difficult to secure, with the result that if the main gear is covered it is sooner or later grinding in dirt and the life of the wheels is always less than when they are left open. The proper meshing of the wheels for all positions of the axle is secured by coupling the axle brackets to the main frame by radius rods pivoted as nearly as possible on the centre line of the intermediate shaft.

On the Sentinel Wagon, built by Alley & Maclellan, of Glasgow, there is a complete departure from the standard practice. The power is transmitted directly from the crank shaft to the main axle by a chain without either an intermediate shaft or gearing, and without provision for two speeds. In order that the road wheels can be made a reasonable diameter and yet keep the travelling speed down to the comparatively slow speed allowed by law, the engine has to be slow running, or else either the crank-shaft pinion would need to be very small or the main gear wheel very large. This in turn means large cylinders, and as mentioned before they are both high pressure. Owing to the use of lift valves they can be worked at an early cut-off except for steep hills. Up to the present, however, no other makers have thought well to adopt this arrangement.

The roller chain now seems to be universal for the heavy machines, the "Silent" chains and similar designs being only used on light machines of the delivery van order.

The next point is wheels, and a few years ago the very name was sufficient to depress steam wagon users. When the tare limit was only three tons it was almost impossible to spare enough weight to make the wheels properly wide for the sake of the roads and yet strong enough for the work. Even now there is a strong feeling among those in close touch with steam wagons that, from the point of view of road maintenance, it would be better to replace an arbitrary tare limit by regulations varying the wheel sizes according to the total load. It can hardly be seriously questioned that a modern steam wagon does less harm to a road that is fit to call a road than is done by the carriage of a similar tonnage by horses, but a few years ago the government regulations compelled makers to use narrow wheels against their own judgment. Of course our legislators did not have to bear the blame, although they were the real culprits.

The three leading types of wheels are the built-up-steel, the wood and the cast steel wheel. Fig. 5 shows a section of the built-up wheel used by the Mann Steam Wagon Co., being given as a representative wheel of its class and because this firm have used this type of wheel from the start. It has gone through many forms, such as flanged plates, etc., but seems to be now pretty well standardised. The boss is of crucible steel, malleable iron or the like, softer materials giving trouble through surface compression causing looseness on the axle. The spokes are cut from mild steel plates, care being taken to mill the edges smooth to prevent cracks starting on the edge and travelling across the spoke. The rim is a special section of mild steel tee bar with extra big corner fillets and a thick table. The whole is hydraulic riveted and the tyre plates are riveted in holes with a countersink carried nearly through the plate so as to hold the plates until they are quite thin. In an earlier pattern of wheel two tee rings were used, side by side, to give a stronger rim, the spoke plates then being straight and parallel to one another. The extra rigidity of the spokes caused them to crack, but the initial bend in the present plates has cured that, while the big corners of the tee rim prevent it cracking at the stalk, as used to happen. The cast steel wheel came into considerable use two or three years ago, being very energetically pushed, but does not seem to retain its position. The boss, spokes and rim were all cast as one casting, the spokes being bent to a sort of S curve to allow of the contraction of casting and to give a little elasticity in use. The wheel is simple, but the castings must be absolutely sound and yet hard, these conditions not being easy to get in steel with absolute uniformity. It has also the drawback of being noisy owing to a noticeable ringing noise set up on stone setts and hard roads.

Of wood wheels probably the best type is the one shown in Fig. 6, which is a patent wheel built by Messrs. Stagg & Robson, of Selby. On early wagons artillery pattern wood wheels were commonly used. In these the inner ends of the spokes are tapered radially in the boss, fitting tightly one against the other, and are bolted between the steel side flanges of the boss. Although perhaps a satisfactory type for wheels which have no driving to do, these proved quite unsuitable for driving wheels on heavy motor wagons. It was impossible to get the spokes to keep tight and as soon as any looseness developed the end of the wheel was near. In the Stagg & Robson wheel the spokes do not touch one another, but each is fitted into a separate pocket in the steel hub. The spokes are inserted from one side and not pushed in radially, the pockets being tapered to be wider at the front side than the back so that when the front flange plate is pulled up by the boss bolts it forces the spoke ends into the tapered pockets. In case of looseness occurring afterwards it is corrected by tightening the bolts and forcing the spokes deeper into the taper. Clearance must be left for this, and soft rubber is inserted to prevent wet getting in and rotting the spoke ends. In a variation of this wheel the rim is of cast steel, with pockets like those in the boss, and the wood spokes are pulled into these pockets at each end.

The Motor Car Act allows the tyre plates to be put on in short lengths provided that the dividing spaces are diagonal and so narrow that on any line drawn across the rim, parallel to the axle, not less than $\frac{7}{8}$ of the width will be tyre and only $\frac{1}{8}$ space. This concession is of considerable value for preventing slipping, and the built-up steel wheel takes full advantage of it as the plates can so easily be fixed or renewed. The wood wheel must have a shrunk-on tyre to bind the wood felloe and spokes together.

and although cross plates can be fastened on they cannot be hydraulically riveted as in the case of the steel wheel.

For these heavy motors two alternative methods of steerage are used; some makers use the form common on motor cars, the Ackermann, in which the front axle is fixed, and carries at each end a short swivelling journal on which the wheels revolve. Although, no doubt, satisfactory for the lighter machines, it is not an ideal arrangement for the heavy ones, as the defects due to the number of parts become more prominent under the heavy loads. There are so many joints and wearing surfaces that the wheels can get very much out of line. On the other hand it allows a shorter wheel base than with the other type of steerage in which the whole axle pivots round a central pin or bracket. This arrangement is copied from traction engine practice and is certainly growing in favour. It has far fewer parts, and even if it is somewhat harder to move the wheels when the wagon is stationary, it is quite as easy to operate when running. The component parts are cheaper when renewals are required, and there are fewer connecting links, rods, etc.

There are many special forms of steam wagons for special purposes, such as street watering, scavenging, etc., and different types of tipping gear, cranes and fittings for special trades, but there are two special purpose machines which are of interest now as meeting the need for special road construction on account of motor traffic. The first is the motor tarsprayer built under the Aitken patents to spray at high pressure. The photograph gives a good idea of the machine, which is a steam wagon carrying a tank of tar and pumps, etc. The hot tar is drawn by a double-cylinder pump from the main tank and is pumped into the circular receiver at the back. This receiver is half full of air compressed to a pressure of 200 to 250 lb. per square inch, and the tar passes from it by downtakes to special nipples which discharge it in a fan-shaped jet on to the road. It strikes the ground with a very high velocity due to the receiver pressure and causes a very definite penetration of tar into the road surface. It is, however, used not merely for tarring existing roads, but for making new tar macadam roads without having to mix the materials beforehand. For this method the nipples are set at an angle, and after spreading each course of road metal, the sprayer traverses the section first in one direction and then in the opposite. This, with the angle of the nipples, projects the tar well below the stones, not merely tarring their upper surface, the operation being repeated for each course of road metal.

The second machine is the patching roller shown in the photograph opposite.

Apart from its small size it differs from the standard types in having the wide roller at the back and steering roller wheels at the front. This makes a short wheel base possible, so that it can rapidly traverse backward and forward over a patch, getting many more traverses per minute than is possible with the ordinary cumbersome large roller. A tank is placed over the back roller for carrying water for ordinary road work or tar for patching tar macadam.

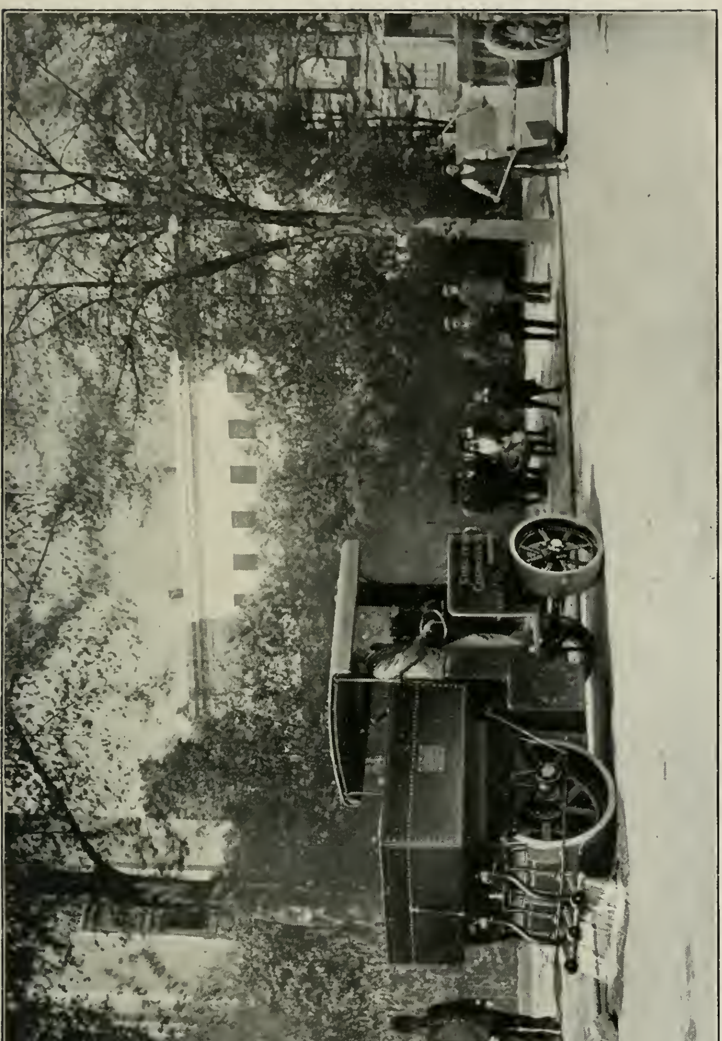
The roller in the photograph was built for Mr. Pickering, of the Cheltenham Corporation, who sends it out on a roving commission to patch all defects that may be found. It draws a trailer of road metal behind, carries its water or tar, and the necessary men, and is fitted with springs so as to work as a motor car and travel quickly between jobs. Mr. Pickering takes the view that to get the best service out of tar macadam any defect must be repaired before water has had any opportunity to penetrate beneath the waterproof surface, and that this cannot possibly be done if the repairs must wait until the big roller is free for the little job. Apart from waterproofed roads, the new trouble of pot-holes opens up a new need for a patching policy.

I have not yet touched on one point of constant interest to a user, viz., the cost of running, and it is a very difficult question to deal with. In papers dealing with this subject, figures are sometimes given which are really taken from makers' catalogues, because it is extremely difficult to obtain accurate figures from reliable users. As a rule a horse user does not really know his haulage cost, and when he changes to motors, even if he can give repair or fuel costs, he knows nothing accurately of either tonnage or mileage.

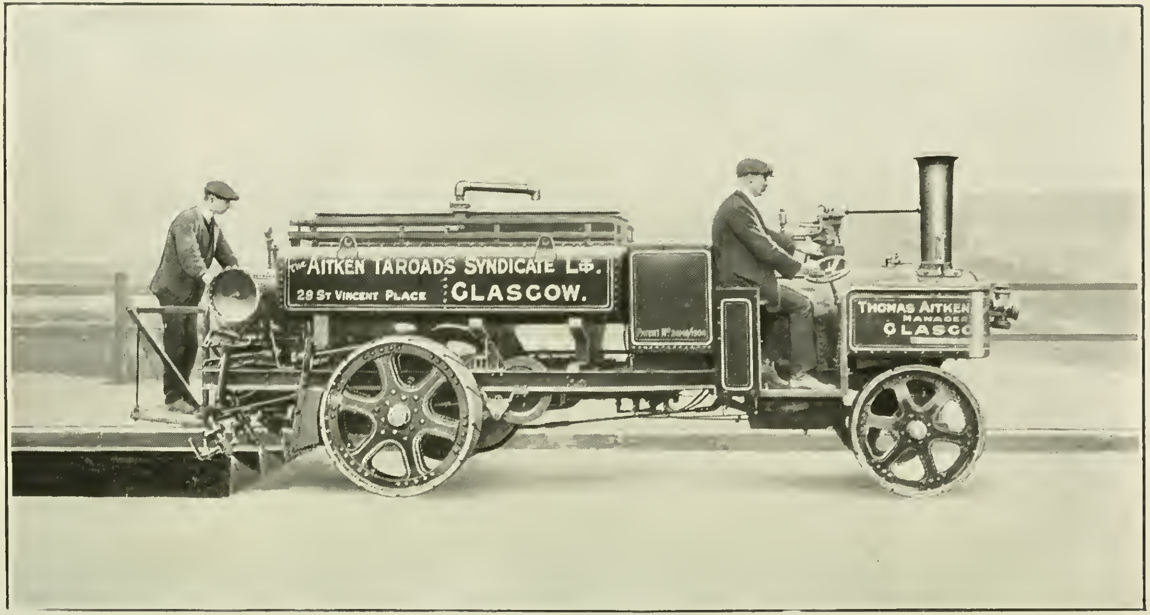
Users' figures vary so much according to the ability of those responsible for the working that it is difficult to decide on one as a fair average specimen. As an example of the differences met with, in going through some accounts with different firms using identical machines on similar work, taking the same twelve months of the machines' life, it was found that the duplicate parts supplied, excluding stores, such as grease, mud door joint rings, etc., vary in value from £2 14s. in one case to £33 14s. 8d. in another, and £10 13s. 11d. in a third. The machines are absolutely identical, the work similar, the usage different, but of course the man who does badly swears that he has a bad machine and abuses the maker, while his neighbour is just as pleased.

In the second case mentioned above it was found that the main axle had been allowed to seize in the differential sleeve for lack of grease, and had big lumps torn out of it as a result, while other parts showed corresponding neglect. On one occasion an eccentric strap was returned on the ground that it must be bad material or it could not have broken, and was found to be as blue as a clock spring as a result of running hot.

In general terms, however, £1 per working day may be taken as an approximate guide to the cost of running a 5-ton wagon. This should allow of say 20 per cent. of the first cost being put



Patching Roller (Cheltenham Corporation).



Aitken Motor Tarsprayer.

aside each year for depreciation and repairs ; these being included in one item instead of separately, so that as the depreciation amount reduces annually the repair allowance may be increased.

For smaller sizes 20 per cent. may also be taken for these two items, wages will be the same and fuel proportionately less, so that the cost per ton-mile would naturally be higher but for the fact that the speed of the smaller sizes is generally higher and partly counterbalances the higher proportion of wages to total running cost.

It is not possible to give the running cost per ton-mile as a general statement, as for a given weekly cost the cost per ton-mile will depend upon the conditions of working. For instance, although with a five-ton wagon running 20 miles out and 20 miles home with a load each way, the cost per ton-mile may be as low as 1¼d., yet with the same wagon running at the same cost per week, this cost per ton-mile may rise to 9½d. if the journeys are short, the load is one way only, and a lot of time is lost in loading and unloading.

Discussion.

The **President,** in moving a vote of thanks to the author, said that the paper which Mr. Cornock had read showed that he had a thorough knowledge of the subject which he had undertaken to lecture upon. No one could peruse the paper without feeling that there was not a single feature of this class of machine to which the author had not given close personal study. It was a most admirable review of the present position with regard to the construction of steam wagons. Personally, he did not feel competent to criticise the details of these machines, because it was purely a mechanical engineering subject, and as a civil engineer it did not come within his practice. The only way in which he personally had to do with this class of machine was in relation to the effect of such machines upon the roads on which they travelled ; in other words, in connection with claims for extraordinary traffic. From that point of view he was not quite prepared to subscribe to the author's suggestion that the tare weight was immaterial to the road authority. The tare weight, it must always be borne in mind, had to be carried by the road on the return journey, and that was an important feature, because in calculating the cost per mile for road maintenance purposes that had to be taken into consideration. He thought that the width of wheels was a very important matter, and one in which the makers should strain every nerve to see that the weight was distributed over the largest possible area. One often saw roads very badly cut up by wheels obviously too narrow for the loads placed upon them. He could quite appreciate the difficulties of the makers in endeavouring to standardise their classes of manufactures. Their customers might ask them to produce the machine to the lowest possible cost, and then it might very often happen that they had a difficulty in making the wheels the proper width. Glancing for a moment at some of the mechanical points —quite as an amateur—he was very interested to learn that the open chain drive was better than a drive with the chain running in an oil bath. He thought that those who had anything to do with cycling rather favoured a gear-case containing an oil bath, but apparently for the heavier machines the open chain was equally, if not more, efficient than one with an oil bath. When going round the works of Messrs. Greenwood & Batley that morning they had seen two motor cabs, one of which was evidently a very old experiment, the other one being now in use, in which the transmission was by means of electricity. The engine drove a dynamo and the dynamo drove a motor. He would like the author to say whether he had ever considered that means of transmission for the class of heavy wagon described in the paper. Then he would like to know with regard to the transmission in Fig. 1, which the author said was limited in length by the diameter of the gear wheels, whether some system of bevel gearing, with a shaft running longitudinally along the machine between the engine and the driving axle, would have been one means of getting over that difficulty. He was sure they would all unite in giving a most hearty vote of thanks to Mr. Cornock for his trouble in preparing the paper, and he hoped that the subject would be thoroughly discussed.

The vote of thanks was unanimously agreed to.

Mr. R. W. A. Brewer said that the subject which Mr. Cornock had dealt with was one of very great importance, particularly at the present time. Moreover, it was put forward in a most excellent manner, and the diagrams were worthy of special mention. The question of steam wagons had really been one of British origin, and English engineers had given more attention to the construction of these machines than anyone else, even more than the French. There were two distinct methods of mechanical transport on roads at the present time: one was steam propulsion and the other petrol propulsion. In any problem of mechanical transport there were those two alternatives. The steam wagon appealed to one as being the means of transporting heavy materials in such a way that the cost of transport, the wear and tear of the machine, and the risk of breakdown should be as small as possible. On the other hand, perhaps the speed was not very great as compared with other types of vehicles. But transport by an internal-combustion-driven machine involved very heavy costs. In the first place, there was the cost of the tyres. It was almost impossible—he thought it a practical impossibility—to run a petrol-driven machine on such wheels and tyres as were referred to in the paper. The vibration was enormous, and, as constructed, the internal combustion engine was a very delicate piece of machinery, being generally considered very much more delicate than the steam engine. Mr. Cornock would probably agree in the statement that it was very difficult to keep even such things as bolts tight in steam wagon work on account of the vibration, so that in internal-combustion-engine-driven machines the question of vibration must be very carefully considered, and for that reason rubber tyres must be used, the cost of which was very heavy. In fact, for a machine of the omnibus type the cost of a set of tyres was £100 to £120, and for commercial work those tyres did not, in many cases, last more than three months, so that their renewal was a very considerable and important item. He was very interested to hear about the chain and gear transmission. He considered the method shown in Fig. 1 to be an extremely heavy and cumbersome arrangement. He quite agreed that, as Mr. Cornock had pointed out, chains had improved enormously during the last few years, but he thought the author was wrong in stating that the roller type of chain seemed to be universal for heavy machines, as it would be common knowledge that the "silent" type of chain was now generally used for 'bus work in London. He also knew that some of the wagons running in London were using that chain. The Scotland Yard authorities had passed an order some time ago, on the recommendation of an engineer, that a foreign chain, which was specified, should be entirely used for this work, and those chains were used accordingly. With regard to the damage done to the roads by the ordinary type of wheel, he was very much opposed to anything so small as a 40in. wheel, but, of course, there were great difficulties in the way of adopting larger wheels. Considering a platform type of machine—say Fig. 3 for convenience—it was essential that the platform should be a reasonable height above the road, and in order to use a bigger wheel it was necessary either to raise the platform or to put splashers on it. Another point not touched on by the paper was that wheel diameter had a great bearing on the question of damage done to the road. Of course, large diameter wheels gave a larger arc of contact on the road and did considerably less damage than small wheels.

Returning to the subject of chains, he would like to ask whether centre or side chains had the best wearing qualities. He would have thought side chains perhaps were better than centre chains because when a wagon ran along a muddy road the mud splashed towards the centre chain, and it seemed that more mud would lodge on that type of chain. Another point on which he would have liked information was with regard to the fuel for firing these machines. A number of machines of this class were built for export where ordinary coal could not be obtained, and he knew of some which were built for coke and wood-burning. There are other fuels which could be used and which were obtainable in certain parts of the world ; it would therefore be interesting to know whether small boilers and fire-boxes, such as were put into these machines, could be used for fuels other than coal.

In referring to the life of these machines, Mr. Cornock had given 20 per cent. as an allowance for depreciation. He would like to know what was the author's experience as to the life of machines of this type, which were the most vital parts, and whether a machine would last five or six years and still remain in reasonably good order. With regard to the method of carrying the side plates to the fire-box (Fig. 1), which were riveted to the rest of the boiler, and using them as main supports, one would have thought that the vibration would tend to loosen the rivets. He did not know whether in fact there was any trouble from rivets loosening in that way.

Mr. Cornock had not mentioned any of the means which might be adopted for fixing the differential when one driving wheel got into a soft patch. It was an important point that means should be devised in these machines for providing a solid drive by simple means in the event of one wheel getting into a soft patch. Still referring to Fig. 1, it had been pointed out that a radius rod was provided between the last countershaft and the back axle. He would like to know, with a revolving back axle, how it was supported—if the parts rode in horn plates or not.

He could not quite make out the legal position of the wheel shown on the Yorkshire wagon, because it was stated in the Act that seven-eighths of metal to one-eighth of space must be provided, as he understood, in a line drawn across the face of the wheel at right angles. Perhaps that law was not very strictly enforced. He would like to relate an incident which had occurred in fighting a case on this tare limit. Mr. Staplee Firth was defending, and the point was whether a certain steam wagon was above the tare limit at the time ; the Act stating that, in arriving at the tare weight, the weight of water, fuel, or accumulators may be deducted. Mr. Staplee Firth had argued that the boiler was an accumulator, because it accumulated steam or energy. He had the boiler removed and weighed the machine without it, and so brought the weight below the limit. His argument was upheld and he won his case.

Mr. W. J. Hadfield said that he had come to that meeting because he was connected with the Corporation of Sheffield, who were thinking of buying steam wagons, and he was anxious to get information about them. The paper had been very interesting, and the author was certainly entitled to the vote of thanks. Mr. Cornock had touched upon a matter he had not expected ; that was the effect of steam wagons upon roads—a very impor tant point. A good deal of information had been given, and he would like to add something from the point of view of those who had to do with roads. He was responsible for the upkeep of 400 miles of highways, including granite paving and all sorts of surfaces, and he desired to emphasise the fact that steam wagons had a far more disastrous effect upon the roads, weight for weight, than horse wagons. In some parts of Sheffield there was a regular service of steam wagons, and they were absolutely smashing the roads up; in fact, it was becoming a question whether wood paving would not be better material for them to travel upon than granite. He had put this down to a great extent to the matter Mr. Brewer had mentioned, namely, the diameter of the wheels. If the wheels were of a larger diameter there would probably be less damage to the roads. That was a point manufacturers might very well consider, because one objection which many people had to the use of steam wagons was that they might get a claim for extraordinary traffic. Was it not for the makers to consider whether they could not do something with the wheels to minimise damage to the roads?

When wood wheels had been mentioned he had hoped to hear something in reference to wooden-shod wheels, and he would like to know whether it was not practicable to use wooden tyres. He had been in Nottingham a short time ago, where the Corporation did a certain amount of haulage by traction engines. The City Surveyor considered that he must set other users an example, and used wooden-tyred wheels, which he (the speaker) understood were manufactured by Burrell's, of Thetford, the tyres consisting of segments of wood. He would suggest that manufacturers of steam wagons might consider whether they could do something of the same kind. There was no doubt that, under certain conditions, a steam wagon with steel-tyred wheels was almost useless, say, on slippery surfaces such as ice, and wooden wheels might then be found more efficient. With regard to the use of petrol instead of steam, he would like to say that the Corporation of Sheffield had tried a petrol engine, and had found the cost of rubber tyres so great that they had to give up the idea.

Mr. J. H. Mann said that the author had covered the ground very fully, and the Society were to be congratulated upon having heard such a very good paper, in which everything was thoroughly well thought out. It was a record of practical experience, and nothing had been exaggerated, while as much as possible had been done to avoid raising a controversy about the different makes of steam wagons. He would like to say a word about the chain drive. Mr. Brewer had said that he thought gear wheels were very cumbersome things, or, in other words, that they were heavier than a chain drive, but the reverse was the case. A gear drive was much lighter than a chain drive. Suppose a pinion were required, and a wheel to give a reduction of speed, say, of 4 to 1. In the case of a gear drive there was a spur pinion and a spur wheel, and that was all. In using a chain drive there was a sprocket pinion and a sprocket wheel, besides which there was a large chain, so that the chain was an additional weight altogether. The sprocket wheels were very little lighter than the spur wheels, in fact, he did not think they were any lighter, but if they were it was so very little that it was hardly worth considering.

There was another point. The author stated that in the chain-driven wagon illustrated, if the sprocket wheels and pinions were taken into consideration, there were the same number of wheels running as in the gear-driven wagon; but in a chain-driven wagon there were the same number of gear wheels running as in the all-gear-driven wagon, with the addition of the sprocket wheel, the sprocket pinion, and the chain. The chain drive was thus altogether an addition. Further, with regard to noise, most makers of motor cars were discarding chains because they were noisy, and some makers of motor wagons advocated chains because they were quiet, which was paradoxical. The noise in the gearing came from the high-speed gear, that is, the gear between the crank shaft and the intermediate shaft. A crank shaft probably ran at 400 to 500 revolutions a minute. The chain-driven wagon had the quick-running gear all the same. To be logical it ought to have the chain from the crank shaft to the intermediate shaft, and not only for the slow-running gear between the intermediate shaft and axle, because the former was the noisy part of the gearing.

Reply.

Mr. J. C. Cornock, replying to the discussion, said that the President's proposal for transmitting the power by an electric generator and motor to obtain the long wheel base without a chain on the overtype wagon, while mechanically possible, was objectionable on the score of initial expense and the difficulty of getting suitable men in charge. The price which could be charged was strictly limited by the fact that these commercial machines had to pay their way against other forms of cartage, such as horses or railways. They were not luxuries for which the owner expected to pay. Apart from this, however, the men who drove these wagons were so frequently quite unfit to have charge of electrical apparatus that a considerable proportion would give bad results. The greatest difficulty in introducing the longitudinal driving shaft was that the steam engine was horizontal in most cases, and being double-acting, was too long to place across the wagon instead of longitudinally.

In the matter of road damage, observation led to the belief that the broad-wheeled motor wagon did less harm per ton of goods, although not perhaps per journey, than an equal amount of horse haulage. Very frequently it was overlooked that on the introduction of a motor wagon service a road, previously almost unused, was used regularly, and usage was naturally followed by wear, no matter whether due to horses or motors.

He could endorse Mr. Brewer's remarks as to the cost of rubber tyres. For a two-ton wagon a set of rubber tyres should not be smaller than twin 5in. on the back wheels and single 5in. on the front ; and the cost would be £100 to £110. The only chance of success for rubber was to have plenty of it, and if an endeavour was made to save first cost by using small tyres, the money might as well be thrown in the gutter. Unlike a 'bus, the motor wagon must go on any road that business demanded, and could not be put on a selected route with good road surfaces, so that the risk of cutting up the tyres quickly was much greater. The Mann's Steam Wagon Co. made a compromise in this matter by fitting their quicker running two-ton wagon with a second set of springs carrying the platform alone, and not the mechanism. This enabled it to run fast on steel tyres, and yet reduced the platform vibration sufficiently for carrying bottles, etc.

He thought it was correct that the "silent" pattern chains were now rarely used for the heavy wagons, and supposed that in the case of 'buses the requirements of Scotland Yard were largely responsible for their use.

Undoubtedly wheels of large diameter were desirable. In fact his firm's belief in this fact had led them never to use wheels less than 42in. in diameter, even in the days when the tare weight was limited 3 tons. It was difficult to go above this or the platform would be too high to suit loading berths already in existence at breweries, mills, etc.

The best place for either chain or gear wheels was, he considered, towards the centre. Having had experience of both positions, he found that less dirt was thrown on than when they were placed near the road wheels, and also that the road wheel could then be placed directly against the bearing, which reduced the bending stress on the main axle.

The difficulties of burning heavy oil fuel in the small boilers, with their small fire-boxes, intermittent loads, and frequent stops for traffic, were very serious. It was very difficult to get perfect combustion, freedom from smoke, and to ensure prompt re-ignition if the fuel had to be cut off for restless horses or traffic stops.

For a modern machine a ten years' life might reasonably be expected, and the machine should then be saleable or a good stand-by machine. There were many of the old light machines now nine years old and still doing good work, although they were never as good as the present types.

The fear of leaky boilers through carrying the engine proved to be quite as unfounded in practice as with traction engines.

The best way to lock the differential gear in the case of slipping wheels was to use a friction strap, as this was not absolutely positive, and therefore did not impose too severe a strain on the axle, and also because it did not require two men to manage it as in the case of a pin locking gear.

Replying to Mr. W. J. Hadfield, the use of wooden treads to the wheels on sett-paved roads would, no doubt, prevent the concentration of the whole weight on one stone, but, unfortunately, where the wheel tread had not only to withstand the speed, but had also the weight to carry, the life was found to be so short as to render their use impracticable. Although a wooden tread wheel was made, it was only intended for use during the comparatively short periods when the roads were frozen and slippery. He thought people often had an exaggerated idea of the wear on macadam roads resulting from steam wagon traffic as compared with horses, just as some might compare one steam wagon with one cart and horse, instead of with the five or eight horses and carts which would be needed to do the same work.

J. C. CORNOCK ON "STEAM WAGONS."

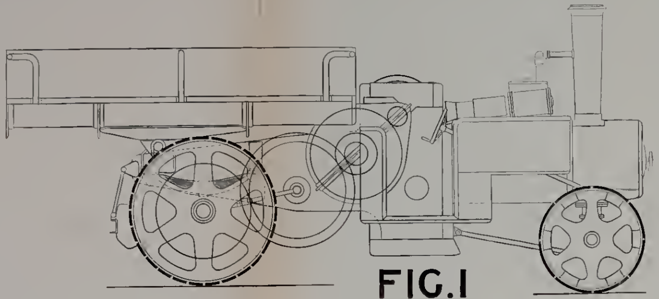


FIG. 1

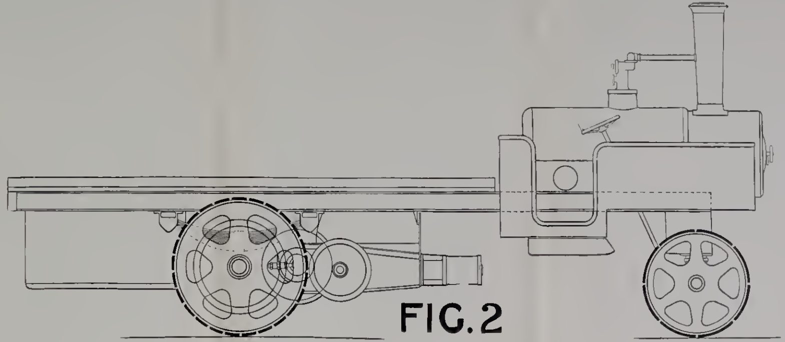


FIG. 2

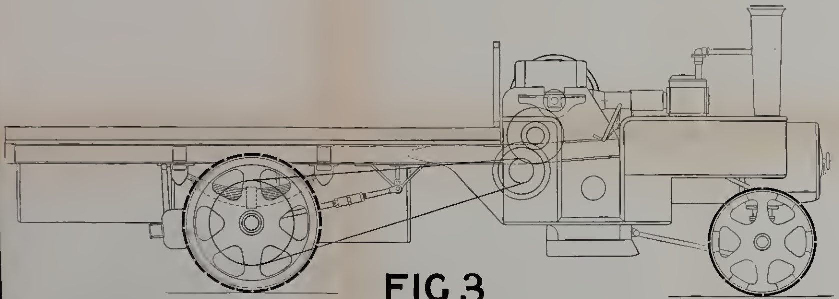


FIG. 3

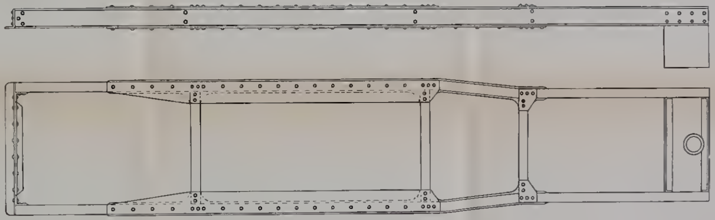


FIG. 4

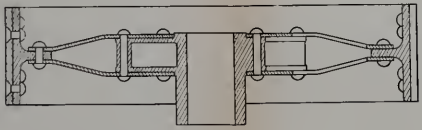


FIG. 5

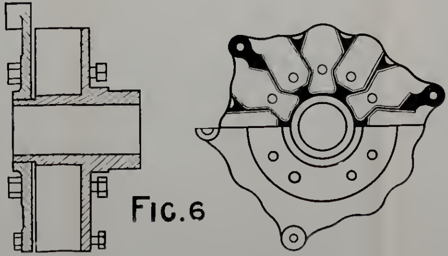
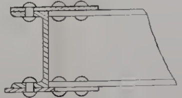


FIG. 6



TRANSACTIONS OF THE SOCIETY OF ENGINEERS, 1909.

December 6th, 1909.

EDWARD JOHN SILCOCK, PRESIDENT,
IN THE CHAIR.

THE MECHANICS OF DUST.

By C. H. W. BIGGS.

> "Man in inquisitiveness should be strong,
> From curiosity doth wisdom flow,
> For 'tis a maxim I've adopted long,
> The more a man inquires the more he'll know."

THE memory of a man is said to retain impressions of happenings during the years of his early life, better than it does those of his later years. Most people entirely agree with this statement—but, as the bull of the Irishman says—with exceptions. Years ago a series of lectures was given upon a special subject. One statement of the lecturer impressed itself to the effect "that reforms" (here the word is used generally, meaning perhaps changes for the better; reforms of all kinds, political, religious, scientific and so on) "that reforms almost always come from without." Put another way this means that reforms do not usually begin with the expert. Later experience shows it is no less singular than true that empiricism does usually make the first step in progress. When the empiric has done something that does something, then the scientific men come along, and show that it cannot be done at all, and if done, is wrongly done, and should neither be nor act.

By the empiric is meant the practical man who does not theorise—he *does*; and theoretical investigation comes after, mostly to wonder, to talk, and finally under compulsion to adopt. The layers of dust have been working by rule of thumb, not from theoretic investigation; yet it is hoped to show that once again the practical man has been working in the right direction.

Let these statements be emphasised, because some men are of those convinced cynics who kick against the conceited scientific theorists most of whom *assume* they know all the factors of the problem, and make theory an end rather than a means.

WATT—Who really invented the steam engine, was not a theorist, only a poor worker.

BRINDLEY—The eminent builder of bridges, canals and tunnels, could hardly sign his own name.

HARRISON—Who introduced the chronometer, was a carpenter.

WYATT—A collector of hair for barbers, gave the clue which Arkwright followed up to success.

CARTWRIGHT—Ignorant of mechanics, laughed at by manufacturers, made weaving of cloth by machinery practicable.

CORT—Did for the iron industry what Arkwright did for the spinning and Cartwright for the weaving industries.

The WRIGHT Brothers, to come nearer home, made flying possible.

In every case the result has been obtained by a system of trial and error. Under trial, error after error has been eliminated till finally success has been achieved. All these things were done against the opposition of manufacturers, the robbery and jobbery of governments, and the ingratitude of nations.

A forcible writer says :—

" It is a singular and mournful fact that every one of the great improvements to which Britain owes her present prosperity has fought its way in the world against clamour, knavery, and contempt."

In the late twenties and early thirties of last century mechanically propelled traffic was advocated and experimentally proved. Clamour, knavery and contempt killed it for the time, till sixty years after it arose again and came this time to stay. Like the advent of the coach, the coming of the motor directed renewed attention to perfecting the construction and maintenance of our roads. The old conditions were met, but the new conditions soon proved the necessity of other methods.

Dust troubles were exaggerated, and the unthinking—that is the bulk of the public—condemned the traffic.

The more thoughtful, however, began to consider :—

(1) Was the new departure an improvement on the old ?
(2) Was it a desirable innovation ?
(3) Had it come to stay ?

Answering these questions in the affirmative others arose.

(1) Could existing roads made for one class of traffic be completely or temporarily adapted to meet the new conditions ?
(2) Could the dust nuisance be obviated, palliated or minimised during the period of change ?
(3) Would the adaptation of the roads be costly or economical ?

It may safely be answered that as the new traffic has come to stay, the roads can, and must be constructed and maintained to carry the traffic. Unless there be an enormous initial expenditure there must be a period of transition during which the roads will be gradually reconstructed to meet the new factors. It must always be remembered too that the traffic also is in a state of transition. In all cases economy has to be considered—but the moral should at every opportunity be driven home to the minds of the great unthinking, densely ignorant public that economy does not consist in not spending, but "in spending wisely." An intelligent, experienced opponent should be the delight of the writer of any paper that pretends to teach something, and it is while touching the subject of economy that debate is challenged here or elsewhere. The columns of figures and the prices thrown at the heads of people are alarming and mostly not worth the paper written on or breath used. Before prices can be of value, there must be a standard of comparison. There is as yet no such standard, hence prices are merely interesting but not rigidly comparable.

The late Prof. Tyndall said that dirt was "matter in the wrong place." Put the "dust of the housewife" in the place of dirt and the definition remains true. A more rigid definition is as difficult as that asked the Professor.

What is matter?—Never mind.
What is mind?—No matter.

Dust is matter—something ponderable, occupying space, and necessarily having shape.

Which of these properties is the most important?

It would be venturesome to say. Each seems as important as the other. From its ponderability—its weight—the measure of the action of gravitation is obtained. The mass—or more colloquially if speaking of one part of the earth's surface—the weight, is necessarily small, very small, in fact, compared with the space occupied; and in this statement lies almost the whole of the secret of the mechanics of dust. Yet the shape or form. giving surface area, plays a very important part; for upon this depends the resultant effect of certain forces.

In the popular sense dust consists of small particles of matter easily made to float about in the air till gravity brings them to rest—often, as the housewife says, where they are not wanted.

One of the earliest things learned by the student in mechanics is that matter is inert, that of itself it cannot start into motion, and if in motion would continue in motion in the same direction without change. Of course to the highly developed scientific mind there is no such thing as rest; all, is motion and matter, but here the talk must be in the ordinary language.

A force or forces must be applied to this small dust mass to give it motion, stop its motion, or change the direction of its motion.

The dust to be considered by road makers and menders is of various kinds and comes from a variety of sources.

There is :—

(1) That put down in many cases by the road maker—evidently a fault to be amended. The road maker again too often, to save a little time, crushes his new material into dust, and destroys what he really wants, and has provided.
(2) That produced by the wear and tear of the road materials. This is an easily measurable quantity and of course depends upon the magnitude and class of traffic, the contour and gradient and other well known conditions.
(3) The droppings from animals and from the traffic, more especially farm traffic.
(4) That conveyed by the winds. The amount of this depends upon the surrounding physical conditions.
(5) That deliberately thrown upon the roads.

Some of this dust is detrimental to health, all of it to comfort.

Dust is found at all altitudes, so before considering palliation or prevention it is necessary to understand something about flotation in air. If the density of the floating matter be the same as the density of the air, the matter will remain in the air wherever it happens to be placed unless acted upon by a force or forces other than gravity. If the density be greater than that of air, then :

(1) Gravity will, unless opposed by other forces, bring the particle to the ground.
(2) Unless the shape causes a displacement of air—as we shape iron to displace and float on water—so dust may float in air.
(3) Masses heavier than air may, acted upon by other forces, float in air, as is shown by recent results in aviation.

If the density be less than that of the air at any point the particle rises till it gets into a stratum wherein the air has the same density.

There is no road material or dust put upon the roads in any way that is not much heavier than air, bulk for bulk, hence none of these things will float about unless because of shape and displacement or being acted upon by a force or forces. Thus we have to consider the forces acting.

Specific Gravity.

Water	= 1·0	Basalt	= 2·8 to 3·2
Air	= 0·0012	Granite	= 2·56 to 3·0
Asphalte	= 1·1	Earth	= 1·5 to 2·0

The one force always acting is that of gravity, and that is the only force naturally acting to bring floating particles of dust to rest.

Quite a number of forces may act to set dust in motion, the extent of the motion, the direction of the particles and their ultimate destination depending on the resultant of these forces.

Few people ever connect the unobserved, unfelt air currents with dust troubles, yet these probably play a more important part in its disposition and distribution than do the more violent air currents recognised as winds. The force exerted by wind is known and has often been measured. Thus :—

Velocity in Miles per Hour.		*Velocity in Feet per Second.*		*Pressure in lb. per sq. inch.*
1·0	..	1·47	..	0·005
10·0	..	14·67	..	0·492
50·0	..	73·35	..	12·300

The pressure can be found from the formula :—

$$V^2 \times 0{\cdot}002288 = P.$$

When V = Velocity in feet per second.

One of the most interesting investigations, and one open to every student, is that of the effect of minute air currents upon dust particles. Imagine for a moment dust particles having very large surface compared with their mass. Fortunately, the student can on occasion easily see such particles and watch their evolutions in a room where otherwise it is almost, if not quite impossible, to detect air currents by other means. Smoke consists of small particles of matter, and is in daily use to detect minute currents of air both in drains and in rooms. There is an excellent way to investigate and to follow the motion even of individual particles. Dr. Travis, in his experimental work on seeing colloidal matter, makes great use of the ultra-microscope. You can get something of this effect in rooms where a window faces a bright sun. Darken the room, leaving only a hole (preferably circular) through which to get a beam of bright sunshine. Thus we get a cone of brilliant light through the room. In this cone you can see dust particles playing all manner of antics, some falling, some rising, some going in one direction, some in another, the direction of the small masses being the direction of the resultant of the forces acting.

Change a force or forces by making a slight, or for the matter of that, a violent movement some feet or yards away from the dust in the cone of light, and you see almost instantly a change in the direction of the dust particles as the wave of air is propagated into the space of the cone.

The antics of the dust particles are very curious to watch, and show clearly and distinctly the fact that however still the air of the room seems to be, there are almost always in the room constantly changing currents influencing the direction of the dust. According to aviators also their machines are susceptible to slight currents not ordinarily noticed.

We must emphasise this action of slight currents because it acts so very largely in the open as well as in rooms.

As has been indicated, not only have mass and density to be considered, but also shape and especially surface area. Just a simple example well known to all, given in most textbooks in regard to air resistance. Take a thin sheet of paper, hold it as high as possible parallel to the floor and let it fall. Gravity does not bring it straight down. The sheet of paper wavers this way and that, coming finally to the floor after having described a series of inclined planes of slight gradient. If the sheet be rolled into a ball it falls practically straight down. In these cases you have the same mass and the same force of gravity, but the air resistance and the phenomena observed are very different. Similarly, different results follow when slight or greater currents of air act upon vastly different surface areas, although the masses may be the same.

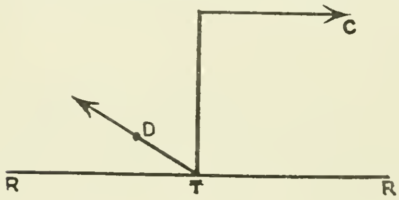
Dust particles have in most cases comparatively large surface areas ; hence, while the air current may be almost imperceptible, they may waver about in the air for a long time, and be carried through long distances, although acted upon by gravity all the time.

This explains one reason for the travel of dust and for its being found at all altitudes. An increase in the force acting increases the distance through which the mass moves, or allows a larger mass to be moved.

The mass moved and the distance through which it is moved in the air against the constant pull of gravity are merely matters of degree depending upon the surface exposed and the velocity of the air current ; that is, to the force or forces and its or their application, other than gravity to which the mass is subjected.

Therefore the *limit in mass* is known (or at any particular place the *limit in weight*) that can be moved under the action of any forces, if we know the quantitative, or for simplicity say the arithmetical value of the forces in operation. If, again, we know the directions in which the forces are acting, the resultant of these directions shows the direction in which the mass will move or tend to move.

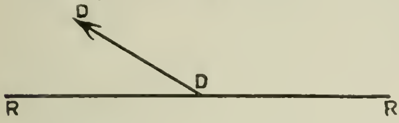
Assume a simple case—such, however, never occurs in practice—of a dust particle upon a dusty road. The road surface is not level, but leave that aside.



Let C represent the wheel axle.
R ,, road surface.
T ,, ,, tire on road.
D ,, ,, Dust particle

The direction of motion of C is shown by the arrow. When T moves, it exerts a force on D tending to move it in the direction of its own motion at the moment of impressing the force.

Roughly, we may represent it thus :—



R R is the road surface.
D D the direction in which D tends to move under the influence of the force exerted by T.

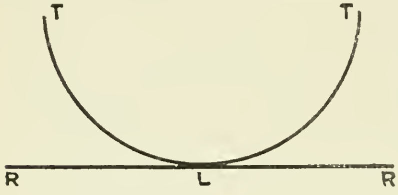
The direction D D is tangential to the curve described by the point T, but D is all the time subjected to another force, that of gravity g, hence if these be the only two forces acting, the direction in which D really moves will be a resultant depending upon the quantitative values of the respective forces. It is well known that the mass direction is a curve, and the mathematics connected therewith are the same as those of a bullet fired from a gun. So far as this simple case is concerned g is constant, the variables being the force impressed and the mass upon which it is impressed.

It is not necessary to enter lengthily upon a thousand and one interesting details as to the formation of dust, yet the action—the real action—of vehicular traffic upon the road surface has been little understood. However, just examine a few of the phases of tire action. Unless there is a perfectly level road surface the tire goes forward in a succession of leaps and bounds. Watch the next baker's or butcher's cart going along a road paved with granite setts. First the bounding tire has a hammering or concussive action—a deliberately breaking action—an action to be avoided. What is the use of true diagnosis to the doctor who will not follow the plain teaching it gives ? Get rid of this action or minimise it as much as possible. Secondly, the revolving action is that of a grindstone, and the grindstone action is accelerated with each bound. We know that the capacity of a grindstone to do its work depends almost entirely upon velocity. The same holds good in the matter of roads and tires. The greater the velocity of the latter the greater the trouble in all directions, especially in the wear of and causing dust from the materials of which the road is made. The extra wear on the sides of setts and hard woods is almost entirely due to the retarding action that goes on there, causing an extra grinding. A very good example of this action is seen when macadam abuts on the setts of the granite crossings to the roads.

It may be well to consider here the much-discussed question of sucking action of soft or pneumatic tires. The simple case before referred to is more of a brushing action, and it is this brushing that primarily starts much of the troublesome dust.

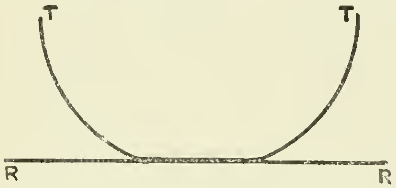
Consider the action of a pneumatic tire upon the ordinary dustbound—or as some say—waterbound, macadam road.

This road consists of a combination of stone with spaces filled with dust and dirt, and others filled with water or air. This last fact is very important. Recognise that the road surface is far from solid, and the spaces not completely filled with solid matter must be filled with either water or air. In wet weather the water permits no dust. That comes in dry sunny weather. Assume dry weather and air-filled voids.



The pneumatic tire is curved in section, and, letting it rest ever so lightly on the road R R the points of contact L will form merely a line upon the surface.

If pressure be forcibly and suddenly applied to the tire it flattens out. This sudden flattening acts upon the air in the voids, that is, the force is transmitted, the ultimate result being that the force so transmitted moves the dust. We all know the pop-gun action, whereby the pellet is forced into motion by suddenly compressing the air. The action of the tire is a modification of that of the pop-gun, and a little thought will show that this result on the dust is greater in the direction in which the tire is moving. You can imitate the action by a puff. The brushing action sends the dust in the opposite direction to the motion of the vehicle, the puffing action sends it in the same direction, but still more largely in the line of least resistance at right angles to the line of tire squeeze. But in the distribution of the dust other forces come into play. The most important, outside the natural forces, are those created by the motion of the vehicle and the wind caused thereby.



Now the distribution of the dust is the prime cause of all the grumbling, and the distribution is carried on in a variety of ways. There are those almost imperceptible air currents to which reference has been made. Their action is easily seen upon a very calm day in dry weather. Take almost any road, bordered by fields and hedge rows. The sun shining upon the white road causes a greater radiation of heat directly over it, than over the adjoining green fields, and over the road there is an upward current of air replaced by currents from either side. These currents cannot be felt, but let a motor come along and then observe what happens. Among the phenomena you can see a fountain-like effect ; dust raised upwards and falling on both sides, the lighter particles being carried long distances. All these little details of distribution are very interesting studies, and will go far to show how very complex are the air currents either when acting directly upon the dust of the road, or upon the dust after being set in motion by other forces.

The title of this paper does not include prevention or palliation, yet the subject is, of course, the text or the moral. There is no intention of dogmatising as to any particular remedy; the aim is correct diagnosis. It is for hearers or readers to find a remedy.

To summarise the results :—

(1) There are a number of forces acting upon road material, one of which is constant, always tending to keep the material quiescent.

(2) All these forces are measurable and limited quantitatively.

(3) The masses which these forces will move are limited.

(4) If, then, the masses dealt with are too large to be set in motion by the forces acting there will be no motion and no dust.

The scientific remedy to get rid of the obtrusive, annoying, unhealthy dust of this kind is *never to have masses of matter acted upon by the forces so small that motion will take place.* If, for example, each mile of road consisted only of one solid block of granite a foot thick, neither the brush action, nor the puff action, nor the wind could move it, nor would concussive action break it up. There would be no dust till the grinding action had produced it or it had been brought from outside. The problem of preventing distribution of the dust is simply to make those dust masses so large or heavy that the forces acting will not raise them in the air.

Is it possible to make the dust particles so large and heavy that the forces acting cannot move them ?

Undoubtedly, the reply is " Yes."

Take the mile of granite, let it be highly polished and unused. Assume no external dust. Before any dust arises there must be wear, and if the worn or ground particles could be kept large enough, under the forces acting there would be no motion and no dust.

But the real particles, either worn from or brought on to the surface, readily form dust, and by cementing or coagulating a lot of particles together, a mass too heavy to be moved as dust can be obtained.

This is really done with the water cart. The action of the water is to cement a lot of particles together. If too much water is used the mud or dirt is too thin, and drops of mud are flung about. Just enough water gives a tougher mud, a better cemented material, with less splashing, and no dust. The action of water, however, is only temporary. If constantly applied and properly done it is expensive.

Instead of water quite a number of cementitious materials have been suggested and tried, most of them depending upon tarry and oily substances for their efficiency. Up to the present no substance has been found that is more than a temporary palliative.

The ideal agglutinative is one that, once incorporated in the road surface, acts till that road surface has to be replaced by a new one, for, after all, a road must be considered as consisting of two parts :—

(1) A more or less permanent foundation.
(2) A wearable, renewable surface.

Restricting attention to macadam roads, the surface of such a road at present consists of :—

(*a*) Stone of some kind.
(*b*) Spaces between the stones filled with binding material.
(*c*) Spaces filled with air or water.

A standard is required by which to measure approximately the perfection of any macadam road :—

(1) Taking the weight of a cubic foot of the stone of which the road is formed.
(2) Taking the weight of a cubic foot of the road as made.

If the weight of solid stone is taken as unity, the weight of the other or the made road will never be unity ; but the nearer it approaches unity the better. On taking sample cubic feet in any road it will be found that the specimens vary exceedingly. If the road is not homogeneous it does not and cannot wear equably.

But this is getting away from the subject. Given a certain weight of stone to be ground to powder, given a weight of added powder from extraneous sources, what weight of an agglutinative or cementing material is necessary to bind together the powder as formed into masses which cannot form dust ? That is the problem. The cementing or agglutinative material must always be there, and if perfection is not absolute, get something always ready to lick up the dust as formed or brought.

This is what has been done by rule of thumb, and the reason why it is done. Two standards are suggested which, if adopted, will enable comparison of costs which at present cannot be made. Of course, the reference is to macadam.

(1) The fraction whose numerator is the weight of a cubic foot of the road as made, and whose denominator is the weight of a solid cubic foot of the stone of which the aggregate is composed. The nearer this fraction approaches unity the better the road.

The truly scientific denominator would be not the solid cubic foot, but another quantity which could be scientifically and accurately determined after considerable experimental work, but this would be no better than the standard given.

(2) The ratio between aggregate and agglutinative should be such that the latter is just enough to cement together in masses too heavy to move under the forces acting, the disintegrated particles of the aggregate and the other dust brought on to the road.

A perfect macadam road depends upon the collective wisdom and ability of four classes of workers :—

First, the selectors of the aggregate. Can they provide, be it Inverkeithing or any other granite, be it selected slag or Kentish rag, an aggregate suitable for the traffic and which will contain within its pores or upon its surface the right proportion of the agglutinative material?

Secondly, the makers of the agglutinative. Can they give us a material not too plastic, harmless to animal and vegetable life? It ought to be odourless, not hurtful to clothes or boots, and possibly antiseptic. It should fill the voids with a waterproof material and be a cushioning and resilient portion of the road ready to act as a cementing material as long as the surface lasts. It wants a lot of virtues and no vices. Of course, to obtain an absolutely perfect material is difficult.

Thirdly, even with materials of the best, improperly mixed, a dustless road cannot be obtained. In the mixing it is probably better to use a machine. It works automatically and uniformly; therefore, the result should be uniform.

Lastly, comes the proper spreading, solidification or consolidation. Here again practice depends too much on the human machine, and therefore equal weights of materials upon equal areas are not obtained.

One other fruitful cause of dust which comes of mistaken notions and methods of consolidation may here be mentioned more at length. Take it that the stone has been duly selected and broken. The aggregate is then very unsymmetrical in shape and should be very angular. Upon this angularity depends much of the goodness or badness of the finished road surface. The angles are the bolts, the interlocking part, which, properly positioned, help to form the whole surface into one compact mass to carry the traffic. But what is done in attempts at quick consolidation, but to get rid of and grind to powder the angles which so much care has been taken to secure? The forcing of angular stones into position by means of a heavy roller means the creation of a good deal of dust, the rounding of the stones, lessening the interlocking capacity, conducing to easier movement under the traffic and thus at once assisting towards an increased rate of wear and tear. Put out of mind for a moment the use of dust preventives, and analyse what goes on over many a mile of macadam road in the latter stages of its making. According to the fashion it must first be rolled dry. What is there to deal with? Stones and voids. At this point all are air voids.

The roller comes on; it crushes off most of the angles, and forces the stone into a position, partly filling the voids with the dust formed in the crushing.

Then comes the wet rolling to fill up the remainder of the void area with other dirt. Ultimately the roller is taken off, and the result obtained is a comparatively smooth surface, but a very bad staying one in every detail. The aggregate is mostly rounded and not interlocked. The voids are filled with dirt to be washed or blown out and give trouble as dust. Half our dust trouble is thus made, and called the result of intelligence. Of course, it is simply an example of the old adage, "Time is money." Time is gained. The real money cost is never known. Lately there has been a moderate return to saner methods, lighter steam rollers and a little longer time. There is a tendency towards wisdom even in these enlightened days. It is just as important in a macadam road as in a sett-paved road that the surface be stone and not joint. Why be satisfied with a surface that has half its superficial area the stone aggregate and the other half dirt? It is unscientific, uneconomical and insanitary. No doubt it will be said that such roads are of the past, and that the future must witness the more extended use of a cementing matrix, but even then too little stone and too much matrix will be bad. Thus wandering a little, but not far, from the subject—dust, the ideals and the steps already taken towards obtaining these ideals have been indicated. It rests with others to use the materials ready to hand to the best advantage and to improve upon the old processes already in vogue.

DISCUSSION.

The **President** moved a vote of thanks to the author, which was carried by acclamation.

He then said that he was not one of those who believed that the dust problem would be solved by any radical change in the construction of roads. Undoubtedly motor traffic had come to stay, and roads capable of carrying that traffic must be provided, but he did not believe that any new material, or any great change in construction, was either desirable or necessary. He thought that improvement must be looked for rather in the use of the best quality of materials and in improved methods. For instance, it was obvious to anyone passing through a limestone district that the material chiefly used in such a district for road construction, namely, the local limestone, was not one which was suitable for the purpose, because, quite apart from the effect of the traffic itself, the very rapid action of the atmospheric influences caused an immense amount of white powdery dust to appear on the surface of the road. The first puff of wind which came blew that light powder over the adjoining fences, and left them with a white coating.

There was one thing which contributed very much to the dust nuisance, and that was neglect in removing the dust from the roads after it had been formed. It was impossible to find any material which would not be made into dust by the attrition of wheeled traffic. If dust when formed were not removed frequently and immediately from the surface of the road, it not only caused the dust nuisance, but by its very presence on the road it increased the wear and tear on the road, and caused the formation of more dust. One of the most important things, therefore, was that there should be a better system of scavenging.

The points raised by the author with regard to the forces acting upon a particle of dust were interesting ; but he should like him to explain how displacement could make a particle of dust lighter than air. The dust which had to be dealt with, being of mineral origin, must of itself be heavier than air, and he failed to see how its shape could displace air in such a way as to make it float in the same way as, say, an iron vessel would float in water by displacing the water. The pressure of air was all over the particle of dust, whatever its shape might be, and he could not quite see how it could be made to float in air.

With regard to the so-called sucking action of the pneumatic tyres of motor-cars, the author suggested that this action was principally due to compression of the air in the interstices of the road, and no doubt that was one of the causes of the motion of dust ; but he thought that there were other causes. One of them was that the rubber tyre was indented by the larger particles, and the indentations were sufficiently marked to lift up little pieces of stone or pebbles. If one watched the track of a motor car in perfectly dry weather he would see little pieces of stone dropping off. That, he thought, was due to the stones being pressed into the surface of the rubber. Again, the tyre, through being spread over a large area of the road surface, excluded all air from the space covered, and, consequently, there was a vacuum underneath the tyre ; then, so soon as the tyre rolled on, the air, rushing in from the sides, caused the smaller particles of dust to be lifted. After that, of course, the larger current due to the passage of the car itself caused those particles to be blown away in the shape of a cloud of dust.

Mr. P. G. Killick said that his experience was more with paved roads than with macadam roads. There were very few macadam roads in his district. One of the principal causes of dust on paved roads was undoubtedly horse droppings. In the case of roads which were washed every night—the Strand, for instance—the marvel to him was where the dust and dirt came from. It seemed almost impossible with any amount of washing to keep wood-paved roads free from dust.

He agreed with the author that sufficient care was not taken in making up macadam roads. In re-metalling and steam-rolling several roads lately he had taken about three inches of the surface off, and very carefully sifted it, afterwards putting the stone back with a layer of new stone on top, and using as little binding material as possible. His experience was that the dust was reduced very much by taking a lot of the dirt from the old macadam before putting the new stone on top.

Mr. R. H. Jeffes said the author's conclusion seemed to be that the most suitable road was one of tar-macadam. There was no doubt that such a road was the most suitable, but it had the objection that it was too costly for general use. Even with roads of this material the dust nuisance would not be entirely done away with. He had some tar-macadam roads to look after, and he found that at certain times they were almost as dusty as roads made of other materials.

The question was, Where did the dust come from ? There was no doubt that a lot of it was due to wearing action on the road itself. He quite agreed with the author that macadam roads had been improperly made in the past. His (the speaker's) practice was to introduce as little as possible of the muddy element in binding. In the case of ordinary macadam roads he used granite chippings as a binder, followed by the cleanest sand he could obtain. There was no doubt that by the use of such a method the dust nuisance was greatly minimised.

In re-surfacing a road he had tried scarifying, scraping off the material to a depth of nearly what was required to be put on, sifting the old material, and re-using the larger portion of it, and he found that very good results were obtained in that way.

His experience was that a scarifier was very useful to a surveyor, but that it ought to be used in reason. Everything depended on the class and the strength of the road that it was used upon. He would not use it upon a weak road.

He believed that the way to minimise the dust nuisance was by the adoption of tar-spraying. The idea of having tar-macadam roads throughout the country must be given up because of the expense. Tar-macadam was very well in the towns, but it could not be adopted universally. There was no doubt whatever that tar-spraying was a great dust preventative. He had to look after about two miles of roads carrying the heaviest traffic out of London. In the early part of the year, before that road was tar-sprayed, the dust was terrible. A census of the traffic upon that road showed that on one day just under 1,500 motor cars passed along the road. The complaints he had with regard to the dust were appalling, but as soon as the road was tar-sprayed the complaints ceased, and he had not had one since. Tar-spraying was therefore most beneficial as a dust preventative and greatly preserved the road.

The author had spoken about the bounding motion of a trap upon a sett road. The same action occurred with a motor on an ordinary road, especially if any little inequality existed in the road surface. It was most noticeable around manholes and in similar places. He had seen great cup-shaped depressions caused by motors tearing out parts of the road surface. He thought that a lot of the wear and of the dust on roads was caused as much by the action he had just referred to as by the sucking action.

If motor cars were compelled to limit their speed to twenty miles an hour there would be much less dust than there was now.

Mr. Henry C. Adams said that of course the dust came from the wear of the roads, and the more even the roads the less the wear. The steam-roller driver was a very great factor in getting a good road. Some men made excellent roads, while others spent twice as much time over a road, and then produced a very poor result.

The wear of a road was largely due to the hammering action of a vehicle passing over a projection, such as a stone, and dropping down on the other side. Whether speed had very much to do with the wear or not was, he thought, a debatable point. Some experiments with reference to the jolting of Panflex spring wheels in passing over obstructions, referred to in a paper read recently before the Royal Society of Arts, showed that the greater the speed the less the vertical movement in a vehicle going over a stone, and the less the vertical movement the less the shock would be as the vehicle came down again. It was obvious that in going over a stone a vehicle with iron tyres would cause very much more destruction to a road than one fitted with these resilient wheels.

The dust nuisance caused by motor cars was considerably greater in the case of low-bodied cars.

He thought that all road surveyors tried to get their roads, as far as possible, with the stones on the surface touching each other, and with as little binding material as possible. Road surveyors did not of choice make their roads half stone and half joints. Even if a road was made of one solid block of granite from end to end there would be dust as the result of abrasion by the vehicles, He understood the author to say that when the size of the dust particles could be regulated the dust nuisance would be prevented ; but how could the size of the particles possibly be regulated ?

As to watering, the author said : " If too much water is used, the mud or dirt is too thin. Just enough water gives a tougher mud and a better cemented material." But if just sufficient water was used to obtain a nice cemented material, there was probably produced a greasy mixture upon which neither man nor animal could stand up, and although the result might be beneficial to the road, the user of the road had to be considered.

Mr. A. S. E. Ackermann said that he differed from the author's statement that Watt was the inventor of the steam engine. That Watt certainly never claimed the invention was clear from the inscription on one of his own engines erected in 1785 for Messrs. Whitbread & Co. The engine was taken down in 1887 and was placed in a museum in Australia. The inscription ran :—

"The steam engine was first invented by the most noble Edward Somerset, Marquis and Earl of Worcester, 1655. Improved by Captain Thomas Savery, 1699. Further improved by Thomas Newcomen and John Cawley, ingenious mechanicians, of Dartmouth, in the County of Devon, 1712.

"The expense in fuel reduced one-half by Mr. John Smeaton, F.R.S., of Austhorpe, in the County of York, civil engineer, 1768.

"Greatly enlarged in its powers and uses, and brought to its present state of perfection by Mr. James Watt, F.R.S., of the City of Glasgow, who received his Majesty's patent, 1769, and, in conjunction with Mr. Matthew Boulton, of Birmingham, F.R.S., obtained an Act for the exclusive privilege for twenty-five years, commencing 1775." Watt's great invention was the separate condenser.

Although in the paper Watt was called "only a poor worker," as a matter of fact, he was a mathematical instrument maker.

Why certain other people were mentioned in the beginning of the paper he (the speaker) did not know, unless it was to imply that they did not know the theory of the matters with which they dealt. As a matter of fact, those pioneers of engineering knew everything there was to know in their days about their subjects, and they could not very well know more!

John Harrison was put down as a carpenter. True, he was a carpenter's son, and for a short while worked in his father's workshop ; but by the age of twenty-two he had made a wooden clock, which could be seen in the South Kensington Museum. He made his first chronometer when he was thirty-five, and by then had had a great deal of experience. It was not till he was sixty-eight years old that he made the chronometer (his fourth) which gained the Government prize of £20,000. It was simply his persistent application that won him success. The paper put the matter in a misleading way. It gave one the idea that a carpenter suddenly thought he would make a chronometer, and did so without any particular knowledge or effort, whereas instead of that being the case, Harrison spent years studying and working at the subject, just as engineers worked at their problems to-day.

Referring to the Wright brothers, anybody who had read their papers knew that they had been experimenting and practising secretly for years, and that they knew everything that was to be known about their subject when they began their real work.

Leaving the historical part of the paper, he would come to the mechanics of it. The C on the diagram on page 230 appeared to be at the wrong point. It should be vertically over T.

When the cart moved forward to the right the point T on the wheel described an epicycloid, and the point T could never, by any possible chance, move to the left of its initial position. Hence the particles of dust would *not* be thrown back relative to the ground, though it would appear as if it were going back because the eye followed the cart, which was going forwards ; and relatively to the cart the particle did move backwards, or rather the cart moved forwards relative to the particle.

The next diagram made it still more clear that a mistake had been made.

Further on the author said : " Secondly, the revolving action is that of a grindstone, and the grindstone action is accelerated with each bound." That seemed to him (the speaker) to imply that the wheel rubbed on the ground instead of simply rolling on it. In other words, that the rim of the wheel in contact with the ground actually had a speed relative to the ground, whereas all points of the wheel in contact with the ground were at rest, except in the case of a locomotive slipping on a greasy rail or something of that kind. Hence the driving wheels of a motor car might have the action mentioned by the author, but not the other pair of wheels or those of a cart. For example, in spinning a ball-bearing top, one never got a greater peripheral speed of the wheel than the speed with which the rim left the table. Of course there was a grinding action in the sense of the tyre settling down between the inequalities of the road.

The author said further on : " The brushing action sends the dust in the opposite direction to the motion of the vehicle." That point he (the speaker) had already dealt with, and hoped he had made it clear what really took place.

Further on the author said : " The sun shining upon the white road causes a greater radiation of heat directly over it." The heat did not come out of the ground, it came from the sun, and though he had a hazy idea as to what the author meant, he thought the author should express himself more clearly on this point.

Mr. W. M. Madden said that he quite agreed with Mr. Ackermann as to the diagrams ; but he thought that when a motor car jumped in going over a rough road, there was time for the engine to race, so that when the wheel came down, for a fraction of a second there was a grinding action. He was not sure about this, but he thought that it was so.

Mr. Ackermann said that that was the case, undoubtedly, as regards the driving wheels, but not with ordinary horse vehicles, to which his remarks were entirely confined.

Mr. Madden said that the only points on which he was inclined to agree with the author were with regard to the heating of a road and the currents of air. He thought that on a very hot sunny day one could see the quiver of the current of air rising from the heated road surface in excess of what was observable in the neighbouring fields.

If one walked across a field upon a gravel path one could see that the quiver was over the gravel path, and not on the side of it. That quiver indicated an upward current of air from the path, which implied a flow from the sides towards the path.

Reply.

The **Author** said that the wheels of motor cars in motion had two actions, one a hammering action, and the other a grinding action. Both increased the size of a hollow at the spot where paved setts joined a macadam road.

Some remarks had been made as to cost. It had been admitted in the discussion that the use of tar, tarmac, or tar-spraying really extended the life of the road. Therefore, although the initial expense would be large, the maintenance would be less, and he had an impression that the economy would be something really tangible, although it was not possible to say exactly what was going to happen when the present mixed traction gave way to mechanical traction.

Traffic at the present time was of a twofold character, horsed traffic—very detrimental to any road—and mechanical traffic, which, as a whole, was not so damaging to the road. He was afraid that that last statement would cause opposition ; but he was convinced that the substitution of mechanical for horsed traffic would lessen the cost of maintenance of roads.

One thing which would have to be reckoned with was the heavy cost of removing the tarry mud which would be produced. At the present time the dust on road surfaces was largely taken away by wind and rain.

Taking the example given in the paper of a road composed of one stone a foot thick per mile, of course, there would be dust upon it ; but if some material could be found which would lick up the dust and make the dust particles coagulate so that none of them should move, there would be no dust nuisance. Wear and tear could not be avoided.

There was no agreement among surveyors as to using the old material taken up from a road which had to be remade. When the old materials were scarified or picked he should reject them as absolutely useless. An alternative was to sift them, throw away the dirt, and use the remains as a foundation for the new material. He had seen cases where the aggregate was almost as angular as when put down, but usually it was rounded. If used as a foundation for new material it formed a cushion, as it were, between the new material and the foundation. If the old road surface was to be used, that was the only way in which it could be used to be of any real utility.

Tar-spraying sometimes succeeded and sometimes it did not succeed. He thought that the effect of tar-spraying did not really last as long as was thought. The tar did not always penetrate, and in that case it was not of very great service. Then the tarry material got on one's clothes and spoilt them. Again, there was danger of the tar getting into the side ditches and doing damage.

No one but an engineer who had lived in a large city had the slightest idea of the amount of waste material dropped upon the streets. One large element in this waste material was the hundreds and thousands of circulars which were given away and thrown down.

Mr. Adams had said that the greater the velocity of a car the less was the shock. He (the speaker) had thought that the impact was due to the velocity multiplied by the weight. It was only another phase of the hammering action. He had also thought that if a vehicle was going at a great velocity and came to an obstruction, the jump would probably be higher than it would if it was going at a small velocity. The hammer action was greatly increased by the velocity, because the momentum of whatever was going to act as the hammer was increased thereby.

Obituary.

Francis Elgar, LL.D., F.R.S., F.R.S.E., whose death took place at Monte Carlo on January 17th, 1909, devoted practically his whole life to marine engineering. He was born at Portsmouth, in 1845, where he gained his early engineering experience in the Royal Dockyard, and in November 1864 joined the Royal School of Naval Architecture and Marine Engineering, in which he spent three years. He subsequently joined the construction staff of Portsmouth Dockyard, leaving in 1871 to take up the responsible post of chief professional assistant to Sir Edward Reed, who had just relinquished the post of Director of Naval Construction. During the following eight years Dr. Elgar designed warships for Japan, Germany, Brazil and other Powers, and in 1880 was appointed adviser upon Naval Construction to the Government of Japan, returning to London in the following year to practise as a consulting naval architect. When the "John Elder" chair of Naval Architecture and Marine Engineering was founded in 1883 at the University of Glasgow, Mr. Elgar was offered and accepted the first professorship, but three years later the Admiralty appointed him Director of Dockyards, where he effected a complete reorganisation of the depôts under his charge. This occupied him until 1891, when he finally severed his connection with the Government and became director and naval architect to the Fairfield Shipbuilding and Engineering Co., of Glasgow, with whom he was associated for fifteen years, many of the largest ocean liners being constructed under his supervision. Dr. Elgar retired in 1906 for the purpose of enjoying a well deserved rest, but shortly afterwards he was asked to accept the chairmanship of Cammell, Laird & Co., and continued to take an active part in the management of the Company.

Dr. Elgar was a Fellow of the Royal Societies of London and Edinburgh, while Glasgow University conferred on him the honorary degree of LL.D. He was on the Councils of the Institution of Civil Engineers and the Institute of Metals, and was connected for many years with the Institution of Naval Architects, having been a member of the Council, Vice-President and Honorary Treasurer. Dr. Elgar was an Honorary Member of this Society from 1886 to the time of his death.

William Andrew McIntosh Valon, who died on July 3rd, 1909, in his 71st year, as the result of heart failure, had been a member of the Society since 1873, and occupied the Presidential Chair in 1893.

Mr. Valon was trained for the profession of a civil engineer under the guidance of Mr. Thomas Cubitt, of Millbank, Westminster, and the early part of his career was largely identified with the gas industry. In 1870 he was appointed Engineer and

Manager of the Isle of Thanet Gas Company, and when these works and the district waterworks were taken over by the Improvement Commissioners, he succeeded to the post of Engineer to the latter body. In 1891 Mr. Valon was appointed Engineer to the Ramsgate Corporation in connection with the improvements then carried out on the sea front, but in 1892 his private practice as a consulting water and gas engineer had grown to such an extent that he thought fit to devote his whole time to consulting work, subsequently transferring his office to London. In addition to his membership in this Society Mr. Valon was a member and Past-President of the Institution of Gas Engineers and the Southern District Association of Gas Engineers and Managers. He became an Associate Member of the Institution of Civil Engineers in 1875, a member of the Institution of Mechanical Engineers in 1880, and an honorary member of the Société Technique du Gaz en France in 1892. Mr. Valon was a Justice of the Peace for the Borough of Ramsgate.

Nicholas James West, who died of pneumonia at the Great Eastern Hotel, London, on July 9th, 1909, was elected as a Member in the year 1870, became a member of Council in 1897, and President in 1905. Mr. West was apprenticed in the works of Messrs. Harvey & Co., of Hayle, Cornwall, engineers, founders and shipbuilders, in which his father was a partner, and from 1865 to 1867 was engaged by the Egyptian Trading Co. for the service of the late Prince Halim Pasha at Redessieh, in Upper Egypt. The estate comprised a large area of high land contiguous to the Nile, and Mr. West's work included the installation of a large pumping plant for irrigation purposes. On the death of his father in 1868, Mr. West succeeded to the position of partner, subsequently becoming director and works manager in the firm in which his early training had been gained. In 1895 he gave up his appointment as engineer to this firm and practised in London as a consulting engineer. He was 69 years of age at the time of his decease, and resided at Torquay up to the time of his death.

William Charles Kernot, M.A., M.C.E., for 26 years Professor of Engineering at Melbourne University, died after a short illness on March 14th, 1909. He was born at Rochford, Essex, in 1845, and went to Australia with his parents when six years of age. His father practised as a pharmaceutical chemist at Geelong, where the future professor received his early education, matriculating at Melbourne University in 1861. He obtained his degree of Master of Arts in 1864, and graduated in the Faculty of Engineering two years later. In 1869 he began lecturing in engineering at the University of Melbourne, being appointed Professor of Engineering in January, 1883. During his varied professional career he was chief of the photo-heliograph party who took observations at Melbourne in 1874 in connection with the transit of Venus, and in 1876 he was associated with Mr. Louis Brennan in the development of the Brennan torpedo which was subsequently purchased by the British Government for over £100,000. He was chairman of the two principal juries on machinery at the Melbourne International Exhibition in 1881, and a member of the Royal Commission on Bridges in New South Wales in 1886. As a jubilee gift Professor Kernot presented to the University of Melbourne, in 1887, the sum of £2,000 to endow scholarships in physics and chemistry. During the railway strike he voluntarily undertook the instruction of new drivers in the use of locomotives, his services being recognised by the Railway Commissioners, who presented to him a gold medal set with diamonds. Professor Kernot happened to reach South Africa during the Boer War, and while travelling through the country was detained for some time as a prisoner of war. He took an active interest in local affairs and assisted largely in the development of the Melbourne Working Men's College, to which he made various gifts. Professor Kernot was a life member of the Society, having been elected in 1873. His funeral was made the occasion of a sympathetic demonstration by the students of Melbourne University and others to whom he had become endeared during his honourable career.

Harry James Molloy was born in Ireland in 1865, and died in the service of the Mysore Government on March 3rd, 1909. Joining the Public Works Department in 1890 as Temporary Assistant Engineer, he was engaged on railways, bridges, roads, buildings, water supply and other works. In September, 1903, he was promoted to the rank of Officiating Executive Engineer and did work in the Kadur District, where he contracted malarial poisoning and was obliged to take furlough for one year. On his return to duty in November, 1908, he was posted to Hassan, where he worked until his death. Mr. Molloy was an Associate Member of the Institution of Civil Engineers, an Associate Member of the Institution of Mechanical Engineers and a Member of the Society of Arts. He became a Member of this Society in 1899.

John Freebairn Stow, engineer and surveyor to the Uxbridge Rural District Council, died in April, 1909. Of Scotch birth, Mr. Stow started life as a midshipman and later conducted surveys in French Guiana, Chili and Southern America. In South Africa he superintended the building of the Vaal River viaduct. Mr. Stow gained distinction as an authority on irrigation and read a paper on that subject before the Society in 1901, for which he was awarded a Society's premium, while he had recently communicated a paper to the Royal Society on "Irrigation Works in South Africa." He was also the author of a work entitled "How to become a Municipal Engineer." Mr. Stow was a Member of the Association of Municipal and County Engineers and was elected into this Society in 1900.

REPORT OF THE COUNCIL

For the period January, 1909, to February, 1910.

THE Council, in presenting their last Annual Report of the work of the Society as at present constituted, desire to congratulate the members upon a successful session, during which the influence of the Society has been extended and strengthened, while its total membership has been slightly increased, the number of members on the rolls on December 31st, 1909, being larger than in any previous year.

The most important event of the fifty-fifth session has been the approval by the members of the scheme (which is referred to in more detail on another page) for amalgamating this Society with the Civil and Mechanical Engineers' Society.

It has been necessary, in view of winding up the Society's affairs, to remove from the register the names of some members whose subscriptions were considerably in arrear, and these, together with deaths and resignations, involved an aggregate loss of forty-six, while forty-seven new members were elected. The total membership at the close of 1909 and the two preceding years is shown in the following table.

Class.	Dec. 31, 1907.	Dec. 31, 1908.	Dec. 31, 1909.
Honorary Members	20	20	20
Members	376	360	352
Associates	152	171	180
Totals	548	551	552

FINANCE.

The Balance Sheet and Revenue and Expenditure Account appear on pages 254 and 255, and show a satisfactory financial result. The excess of Income over Expenditure amounts to £41 11s. 7d., as compared with an adverse balance of £6 7s. 1d., in 1908. Among the liabilities, Sundry Creditors show a decreased amount as compared with the previous year, but the Accumulated Fund has been reduced by writing off depreciation in value of investments. The subscriptions in arrear are rather heavier than in 1908, but less than in 1907.

Two new investments have been made in connection with the Nursey Memorial Fund, and the J. Bernays Legacy ; while the Bessemer Trust Fund appears on the Balance Sheet for the first time.

From the Income and Expenditure Account it will be seen that the cost of printing Transactions is low as compared with previous years, and that there has been an increase in general printing due to increased circularization in connection with the amalgamation, the employment register, and other matters.

The Council have heard with regret of the deaths of seven members, including Dr. Francis Elgar, F.R.S. (Hon. Member), Messrs. W. A. M. Valon and N. J. West (Past-Presidents), and Prof. W. C. Kernot, of Melbourne University, who had been a Member since 1873.

Amalgamation and Incorporation.

The amalgamation of this Society with the Civil and Mechanical Engineers' Society has been satisfactory concluded. Proposals for uniting the two Societies had been made more than once previously, but did not advance beyond the stage of preliminary negotiations. After the appointment of Mr. A. S. E. Ackermann, Honorary Secretary of the Civil and Mechanical Engineers' Society, as Secretary of this Society, the matter was vigorously taken up and has now been brought to a successful issue. Details of a provisional agreement were decided upon at a joint meeting of representatives of the Councils of the two Societies held at 17, Victoria Street, Westminster, on March 10th, 1908, being afterwards confirmed by the respective Councils. It was then ordered that new By-laws should be drafted by the Secretary and considered by representatives of both Societies, who discussed the proposals very fully. After four drafts of the new rules had been made, one was finally approved and submitted to the Hon. Solicitors of this Society, in conjunction with Mr. R. H. Willcocks, Hon. Solicitor to the Civil and Mechanical Engineers' Society, and early in May, 1909, they unanimously recommended the Councils to take this opportunity to apply to the Board of Trade for a licence of incorporation. The suggestion was acted upon, the by-laws being redrafted in the form of a Memorandum and Articles of Association as well as By-laws, and again undergoing very careful revision. The resulting draft was printed and circulated to all the Members of Council of both Societies, being finally approved with some minor alterations on September 15th, 1909, the Council of the Civil and Mechanical Engineers' Society having given their approval on the preceding day. At the end of September the eighth draft of the Articles and By-laws and a printed circular, with a voting form attached, were sent to all members of the two Societies with the request that they would record their approval, disapproval or neutrality, as the case might be, in regard to the proposals submitted to them. The result of the poll was a direct confirmation of the Council's proposals, as although fifty per cent. of the members voted, not one adverse vote was recorded. On November 19th, 1909, a special meeting of the Society was held at 17, Victoria Street, Westminster, when the following resolutions were unanimously passed :—

1. That this Society may be amalgamated with the Civil and Mechanical Engineers' Society, and that such amalgamation be effected by means of the formation of a new Society to be known as "The Society of Engineers (Incorporated)," with the object (inter alia) of acquiring all or any part of the undertakings and assets of this Society and the said Civil and Mechanical Engineers' Society, in accordance with the proposition contained in the printed Report already submitted, together with a print of the Memorandum and Articles of Association and By-laws of the said Society of Engineers (Incorporated), to the Members of this Society.
2. That the Council of this Society be authorised to transfer the whole of the undertakings, assets and funds of this Society to the said Society of Engineers (Incorporated), and to take the necessary steps to wind up the affairs of this Society.

These resolutions were submitted for confirmation at a second Special Meeting held at the same place on December 21st, 1909. and were duly confirmed. Similar resolutions received the unanimous approval of the members of the Civil and Mechanical Engineers' Society who were present at special meetings of that Society held at 25, Victoria Street, Westminster, on November 4th, and December 7th, 1909, respectively. The Hon. Solicitors were therefore instructed to apply to the Board of Trade for their approval of the Memorandum and Articles of Association and By-laws as then drafted.

The legal formalities and the requirement by the Board of Trade of a ninth draft of the Articles and By-laws involved considerably more delay than was anticipated in the formation of the new Society, and the incorporation therefore dates from February 28th, 1910.

The Council feel assured that the voting on the question of the amalgamation indicates that the members of the old Societies will give their hearty support to the new one, and that the provisions of the Articles of Association and By-laws will tend to attract new members, on account of the wide extent to which members of the new Society will be able to take part in the management of its affairs and to obtain a vote of all the members on any matter affecting the welfare of the Society or the engineering profession.

The voting powers and other benefits in which members of the Society of Engineers (Incorporated) will participate are such as no other similar body offers, and it may reasonably be anticipated that the union of the two existing Societies will result in their influence and numerical strength being largely augmented.

Meetings.

During the fifty-fifth session the work of the Council has increased as compared with former years, necessitating twelve Council meetings and twenty-two meetings of the various committees. Four visits to works of engineering interest took place in the summer vacation and a provincial meeting was held at Leeds on November 27th. Eight Ordinary Meetings have been held during the year, the last three being at Caxton Hall, Westminster, instead of at the Royal United Service Institution as formerly. In addition to these there have been two Special General Meetings and the Annual General Meeting.

The attendance at the Ordinary Meetings has been fairly maintained, but it is hoped that under new auspices a still larger number of members will attend and introduce friends to take part in the discussions.

Papers.

The following papers have been read and published in the part-form Transactions during the year.

Feb. 1.—President's Inaugural Address, by E. J. Silcock, M.Inst.C.E., F.S.I., F.G.S.

Mar. 1.—A New Test for Concrete, by J. S. Owens, B.A., M.D., A.M.Inst.C.E.

April 5.—The Corrosion of Steel Reinforcement in Concrete, by E. R. Matthews, A.M.Inst.C.E.

May 3.—The Influence of Rainfall on the Design of Sewers, by C. A. Battiscombe.

June 7.—The Sinlumkaba (Burma) Ferro-concrete Bridge, by W. E. Haldwell.

Oct. 4.—The Status of the Engineering Profession, by G. Allan Thomas, A.M.I.Mech.E.

Nov. 5.—Some Observations on the Chemistry and Bacteriology of Sewage Purification, by D. Sommerville, B.A., M.D., D.P.H.

Nov. 27 (Leeds Meeting).—Steam Wagons, by J. C. Cornock, A.M.Inst.C.E.

Dec. 6.—The Mechanics of Dust, by C. H. W. Biggs.

PREMIUMS.

The following authors of papers read at the Ordinary Meetings have been awarded premiums by the Council :—

1. To Dr. David Sommerville, the President's Gold Medal.
2. To Mr. E. R. Matthews, the Nursey Premium of Books.
3. To Mr. W. E. Haldwell, a Society's Premium of Books.

THE STATUS PRIZE.

By the generosity of Mr. A. S. E. Ackermann, the Council have been enabled to institute a premium under the above title. Beginning with the year 1909, this prize is to be awarded each year up to and including 1913 (if papers of sufficient merit are received) for the best essay on " How to Improve the Status of Engineers and Engineering, with Special Reference to Consulting Engineers." This year a number of good essays were received and the prize was awarded to Mr. G. Allan Thomas, the paper being read at the Ordinary Meeting on October 4th, 1909, and published in the Transactions (page 147). Full particulars of the conditions have been already sent to all the members, and will be forwarded on application to the Secretary, the competition being open to everyone except Members of Council.

VISITS TO WORKS.

During the Summer Vacation, four half-day visits were made to the works enumerated below, of which a detailed account is given in the Transactions (page 141) :—

May 12th, 1909.—Messrs. Vickers, Sons and Maxim's Erith Works.

June 16th, 1909.—The London Hydraulic Power Company's Power Station, Westminster.

July 14th, 1909.—Greenwich Power Station (L.C.C. Tramways).

Sept. 22nd, 1909.—Messrs. Wm. Hill and Sons' Organ Building Works.

In addition a meeting was held at Leeds on November 27th, 1909, when visits were paid to Messrs. Greenwood & Batley's Engineering Works, and to a street improvement in course of construction by the City Corporation ; the afternoon being occupied with the reading and discussion of a paper on " Steam Wagons," by J. C. Cornock, A.M.Inst.C.E. This meeting is fully reported on page 203 of the Transactions.

Annual General Meeting.

The Annual General Meeting of the fifty-fifth Session was held on December 13th, 1909. In view of the fact that the Society's affairs were about to be handed over to the new Society, no ballot was taken for the election of the Council and the proceedings were merely formal.

Annual Dinner.

The fifty-fifth Annual Dinner was arranged to be held on December 15th, 1909, but the Council, having regard to the imminent dissolution of the existing Society, decided that it would not be appropriate to hold the usual Dinner this year, but instead a Dinner to celebrate the amalgamation of this Society with the Civil and Mechanical Engineers' Society was arranged to take place on January 19th, 1910, for the purpose of inaugurating in a fitting manner the inception of the new Society. A full report of the very successful celebration of the amalgamation is to be found in the January issue of the new Society's Journal (page 1).

Reading Room and Library.

The Society continues to exchange Transactions with the leading British, Colonial and Foreign Engineering Societies, the volumes being available for reference by members. The proprietors of the principal engineering periodicals supply copies of their publications for the Society's use, and the current issues of these Journals may be seen at the Offices.

The following periodicals have been added during 1909 :—

Crystal Palace Old Students' Magazine.
Engineering Record (New York).
Ferro-Concrete.
Local Government Review.
Scientific American.
Southern Builder.
Surveying and the Civil Engineer.

The Library contains a number of useful volumes, but it is rather deficient in modern works, and it is hoped that members, especially those who are authors of books, will assist in making the Library of more practical value by presenting recently published standard works for the use of the new Society. All such gifts will be acknowledged from time to time in the Society's Journal.

The Council in their Report for the year 1907 stated that it was proposed to form a card-index catalogue of the library books, but this matter has been deferred until the collection has been brought up to date in the manner suggested above, in order that the trouble and expense of preparing the catalogue may be thoroughly justified.

Practical Assistance to Members.

Employment Register.—Strenuous efforts have been made to make this register better known to employers of engineering assistants, but the result has been rather disappointing, letters to the press, and other means of publicity having served principally to bring in applications from those seeking positions rather than from those offering them.

In a few instances, however, the Society has been the intermediary in filling vacant engineering posts, and it is probable that the general depression in business circles may account for the comparative inadequacy of the results of the first year's working.

The Council will appreciate any assistance that members can render in making the register more generally known among employers.

Legal Advice.—The arrangement by which members might obtain free legal advice on professional matters has not been taken advantage of by the members, but the Council desire to draw attention to the fact that that arrangement is still in force.

In conclusion, the Council wish to thank all the members for their co-operation in the past, and to urge upon them the desirability of giving their hearty support to the incorporated Society, and according it that measure of personal interest which will ensure the work of the two constituent societies being carried on with increasing vigour and success.

February, 1910.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1909.

Dr.

Year ended 31 Dec., '08. £ s. d.	EXPENDITURE.		£ s. d.
252 7 5	To Printing Transactions	£139 7 8	
27 4 5	*Less* Sales	10 19 7	
225 3 0			128 8 1
110 4 0	,, Rent of Offices and Hire of Rooms		112 6 0
210 0 0	,, Salary of Secretary		210 0 0
49 14 5	,, Stationery and General Printing		72 0 1
17 4 0	,, Reporting Meetings		17 17 0
6 7 7	,, Refreshments for Members at Ordinary Meetings		8 0 0
17 17 8	,, Fuel, Lighting, Office Cleaning and Repairs		18 16 10
58 6 5	,, Postage, Telegrams, Carriage and General Expenses		93 15 1
19 6 11	,, Dinner Balance		
60 10 1	,, Conversazione		
10 6	,, Law Charges		5 17 6
5 16 10	,, Depreciation on Office Furniture		5 5 2
	,, Balance carried to Accumulated Fund Account—Excess of Income over Expenditure for the year		41 11 7
£781 1 5			£713 17 4

Cr.

Year ended 31 Dec., '08. £ s. d.	INCOME.	£ s. d.
691 8 6	By Subscriptions for the year—*Less* Amounts written off	627 7 6
5 18 10	,, Life Subscriptions—Proportion for 1909	5 7 0
56 3 6	,, Admission Fees (including £18 18s. unpaid at date	57 4 6
3 18 2	,, Interest on Deposit	4 8 4
17 5 4	,, Interest on Investment (London and North-Western Railway Co. 3 per cent. Debenture Stock)	19 10 0
6 7 1	,, Balance carried to Accumulated Fund Account—Excess of Expenditure over Income for the year	
£781 1 5		£713 17 4

LIFE MEMBERSHIP FUND.

£ s. d.		£ s. d.
5 18 10	To Revenue Account Proportion for the Year	5 7 0
53 9 7	,, Balance to be carried to next Account	48 2 7
£59 8 5		£53 9 7

£ s. d		£ s. d.
59 8 5	By Balance brought from last Account, being unexhausted Balance of the Fund on 31st December, 1908.	53 9 7
£59 8 5		£53 9 7

PREMIUM FUND.

£ s. d.		£ s. d.
15 9 0	To Premiums	17 2 0
32 8 1	,, Balance to be carried to next Account	23 1 7
£47 17 1		£40 3 7

£ s. d.		£ s. d.
32 1 7	By Balance brought forward from 31st December, 1908	32 8 1
10 10 0	,, President's Donation	
5 5 6	,, Interest on Investments	7 15 6
£47 17 1		£40 3 7

BALANCE SHEET, DECEMBER 31, 1909.

LIABILITIES.

Year ended 31 Dec., '08. £ s. d.			£ s. d.
144 19 11	To Sundry Creditors		140 16 4
25 7 0	,, Subscriptions Received in Advance. ...		32 9 0
53 9 7	,, Life Membership Fund		48 2 7
32 8 1	,, Premium Fund		23 1 7
20 0 0	,, Special Fund		15 0 0
	,, Bessemer Trust Fund		154 9 6
46 4 5	,, Nursey Memorial Fund		46 4 5
25 0 0	,, J. Efrnay's Legacy		25 0 0
	,, Status Fund		12 12 0
	,, Accumulated Fund—		
	Balance at 31st December, 1908	£853 9 6	
853 9 6	*Add* Excess of Income over Expenditure for the year 31st December, 1909	41 11 7	
		£895 1 1	
	Deduct Depreciation in value of Investments	82 6 10	812 14 3
£1,200 18 6			£1,310 9 8

ASSETS

Year ended 31 Dec., '08 £ s. d.			£ s. d
183 7 6	By Subscriptions in Arrear ...	£194 12 6	
11 11 0	,, Admission Fees in Arrear ...	18 18 0	
194 18 6		213 10 6	
100 0 0	*Less* Reserve against Bad Debts	100 0 0	
94 18 6			113 10 6
352 0 10	,, Cash at Bank—		
	Current Account	61 14 0	
	Deposit Account	220 0 0	
	Special Account	15 0 0	296 14 0
5 17 6	,, Cash in hands of Secretary		3 3 6
	,, Investments—		
606 0 0	£606 London & North-Western Railway Co. 3 per cent. Debenture Stock	524 19 0	
	£33 Hammersmith & City Railway Consolidated Ordinary Stock	46 7 3	
	£13 North & South-Western Junction Railway Stock ...	22 16 3	
	£185 North-Eastern Railway Irredeemable 3 per cent. Debenture Stock	154 9 6	748 12 0
52 11 8	,, Office Furniture		47 6 6
40 0 0	,, Library		40 0 0
38 19 0	,, Stock of Transactions		38 13 0
10 11 0	,, Sundry Debtors		11 16 5
	,, Amalgamation Expenses— Board of Trade Fee and Solicitors' Disbursements		10 13 9
£1,200 18 6			£1,310 9 8

We beg to report that we have audited the Balance Sheet of the Society of Engineers dated 31st December, 1909, and above set forth, together with the annexed Statements of Account. We have obtained all the information and explanations we have required. In our opinion the Statements are correct, and the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Society's affairs, according to the best of our information and the explanations given to us, and as shown by the books of the Society.

17th February, 1910.

(Signed) **ALLEN, BIGGS AND CO.**, Chartered Accountants,
147, Leadenhall Street, London, E.C.

PREMIUMS AWARDED FOR 1909.

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At the first Ordinary Meeting of the new Society formed by the amalgamation of this Society with the Civil and Mechanical Engineers' Society, the following Premiums, awarded for papers read before the Society of Engineers in 1909, were presented, viz. :—

The President's Gold Medal to :

Dr. David Sommerville, for his paper entitled Some Observations on the Chemistry and Bacteriology of Sewage Purification.

The Nursey Premium of Books to :

E. R. Matthews, for his paper on The Corrosion of Steel Reinforcement in Concrete.

A Society's Premium of Books to :

W. E. Haldwell, for his paper on The Sinlumkaba (Burma) Ferro-concrete Bridge.

SOCIETY OF ENGINEERS.

INDEX TO TRANSACTIONS

1857 TO 1909.

AUTHORS.

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
ABEL, C. D.	The Patent Laws	1865	25
ACKERMANN, A. S. E.	British and American Coal-cutting Machines.	1904	71
ADAMS, H.	President's Address	1890	1
ADAMS, J. H.	President's Address	1875	1
ADAMS, T.	The Friction of the Slide-valve, and its Appendages.	1866	6
ADAMS, W.	President's Address	1870	1
ALFORD, C. J.	The Mineralogy of the Island of Sardinia.	1879	93
,, ,, ...	Appendix to Above: Laws relating to Mining.	1879	106
,, ,, ...	Engineering Notes on Cyprus ..	1880	131
ALFORD, R. F. ..	The Fell Engines on the Rimutakai Incline, New Zealand.	1882	121
ALLAN, G. W.	Marine Insurance	1858	14
ALLANSON-WINN, R.G.	Foreshore Protection, with special reference to the Case System of Groyning.	1899	133
,, ,, ,,	Deep Sea Erosion and Foreshore Protection.	1904	141
,, ,, ,,	Submerged Chain Cable Groynes..	1906	13
ALLEN, A. H.	The Engineering Pros and Cons of the Metric System.	1908	125
ALLEN, A. T.	Concrete Subways for Underground Pipes.	1901	99
AMOS, E. C.	Machine Tools	1899	51
AMOS, JAMES	The Machinery employed in laying the Atlantic Cable.	1858	13
,, ,, ...	The New Hydraulic Machinery for lifting Vessels in the Thames Graving Dock.	1859	17
ANDERSON, CHRIS. ..	The Feasibility and Construction of Deep-sea Lighthouses.	1883	45
ANDRÉ, G. G.	The Ventilation of Coal Mines ..	1874	28
,, ,, ...	The Application of Electricity to the Ignition of Blasting Charges.	1878	123
ANDREWS, J. J. F. ..	Ship Caissons for Dock Basins and Dry Docks.	1890	189
ANDREWS, T.	The Strength of Wrought-iron Railway Axles.	1879	143
,, ,, ...	The Effect of Strain on Railway Axles, and the Minimum Flexion Resistance-Point in Axles.	1895	181
,, ,, ...	Effect of Segregation on the Strength of Steel Rails.	1902	209
ANSELL, W.	The Electric Telegraph	1857	11

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Atkinson, J.	Apparatus for Utilising the Waste Heat of Exhaust Steam.	1878	167
Ault, E.	The Shone Hydro-Pneumatic Sewerage System.	1887	68
Baillie, J. R.	President's Address	1889	1
Baker, T. W.	The Utilisation of Town Refuse for generating Steam.	1894	183
Baldwin, T.	Single and Double Riveted Joints	1866	150
,, ,, ...	Experimental Researches into the Nature and Action of Safety Valves for Steam Boilers, &c.	1867	23
Bamber, H. K. ..	Water, and its Effects on Steam Boilers.	1867	65
Bancroft, R. M. ..	Renewal of Roof over Departure Platform at King's Cross Terminus, G.N.R.	1887	125
Barber, J. P.	President's Address	1903	1
,, ,, ...	Notes on the Proposed By-laws of the London County Council with respect to House Drainage.	1897	17
Barker, C. M. ..	The Prevention of Leakage in Gas and Water Mains.	1869	79
Barker, E. D. ..	Hydraulic, Continuous and Automatic Brakes.	1879	75
Barker, Capt. W. B.	International System of Marine Course Signalling.	1884	47
Barnett, S.	The Value of Exhibitions as Aids to Engineering Progress.	1883	75
Bartholomew, E. G.	Electric Telegraphy, irrespective of Telegraphic Apparatus.	1869	55
,, ,,	Electric Telegraph Instruments ..	1872	53
,, ,,	Electric Batteries	1872	77
Battiscombe, C. A.	The Influence of Rainfall on the Design of Sewers.	1909	93
Beaumont, W. W. ..	President's Address	1898	1
,, ,, ..	Modern Steel as a Structural Material.	1880	109
,, ,, ..	High-pressure Steam and Steam-engine Efficiency.	1888	221
,, ,, ..	Road Traffic in and near Large Cities. (Topical Discussion.)	1903	23
Beaumont, W. W., and Sellon, S. ..	Notes on Parliamentary Procedure as affecting Light Railways and Tramways.	1895	33
Behr, F. B.	The Lartigue Single-rail Railway	1886	163
Bellamy, H. E. ..	Australian Timber Bridges	1902	63
Bellasis, E. S.	The Roorkee Hydraulic Experiments.	1886	41
Bernays, J.	President's Address	1880	1
,, ,, ...	The New Pits and Hauling Machinery for the San Domingos Mines in Portugal.	1879	29

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
BIGGS, C. H. W. ..	Depreciation of Plant and Works under Municipal and Company Management.	1902	271
,, ,, ..	The Mechanics of Dust	1909	225
BIGGS, C. H. W., and BEAUMONT, W. W.	Notes on Electric Light Engineering.	1882	23
BINYON, A. H. ..	Notes on Electric Traction	1900	103
BJÖRLING, P. B. ..	Direct-acting Pumping Engines ..	1877	79
BLACKBOURN, J. ..	The Action of Marine Worms, and Remedies applied in the Harbour of San Francisco.	1874	111
BOLTON, R.	The Application of Electricity to Hoisting Machinery.	1892	79
BOWER, G.	The Preservation and Ornamentation of Iron and Steel Surfaces.	1883	59
BOWERS, GEORGE ..	The Permanent Way of Railways	1857	11
BOYD, R. N.	Collieries and Colliery Engineering	1893	169
,, ,, ...	A Deep Boring near Freistadt, Austria, by the Canadian System	1894	119
BRADLEY, B. L. ..	The Grindleford Stone Quarries and their Working.	1905	201
BREWER, R. W. A. ..	Liquid Fuels for Internal Combustion Engines.	1907	158
,, ,,	The Flow of Liquid Fuel through Carburettor Nozzles.	1908	197
BRIGG, T. H.	The Mechanics of Horse Haulage..	1896	21
BROTHERS, W. H ..	Weighing Machinery and Automatic Apparatus in connection therewith.	1890	55
BROWNING, C. E. ..	The Strength of SuspensionBridges.	1858	11
,, ,, ..	The Extension and Permanent Set of Wrought Iron.	1858	15
BRYANT, F. W. ..	Piling and Coffer Dams	1859	38
,, ,, ...	President's Address	1869	1
BUCKHAM, T.	The Drainage and Water Supply to the Town of Fareham.	1869	41
BURROWS, E.	Blake's Bridge, Reading	1893	71
BUTLER, D. B. ..	President's Address	1904	1
,, ,, ..	Portland Cement, some Points in its Testing, Uses and Abuses.	1895	61
,, ,, ..	The Effect of Admixtures of Kentish Ragstone, &c., upon Portland Cement.	1896	179
,, ,, ..	Certain Vexatious and Fallacious Cement Tests now in Vogue.	1903	89
CAREY, R.	Hydraulic Lifts	1893	101
CARGILL, T.	President's Address	1877	1
,, ,, ...	Railway Bridge at the Place de l'Europe, Paris.	1866	191
,, ,, ...	Floating Breakwaters	1871	146
CARPENTER, C. C. ..	Modern Coal Gas Manufacture ..	1891	61

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Carrington, W. T.	Generation and Expansion of Steam	1858	15
,, ,,	Pumping Engines	1859	19
,, ,,	President's Address	1865	1
Carter, J. H.	Roller-Milling Machinery	1883	125
Case, G. O.	Submarine Groyning	1906	107
Chatley, H.	Mechanical Flight	1908	241
Cheesewright, F. H.	Breakwater Construction	1890	83
Church, Jabez	President's Address	1872	1
,, ,,	President's Address	1873	1
Church, Jabez, jun.	President's Address	1882	1
,, ,,	President's Address	1883	1
Colam, W. N.	Cable Tramways	1885	69
,, ,,	President's Address	1891	1
Colburn, Zerah	President's Address	1866	1
,, ,,	The Relation between the Safe Load and Ultimate Strength of Iron.	1863	35
,, ,,	Certain Methods of Treating Cast Iron in the Foundry.	1865	77
Conradi, H.	Stone-sawing Machinery	1876	135
,, ,,	Cleaning of Tramway and other Rails.	1893	47
,, ,,	The History of Mechanical Traction on Tramways and Roads.	1908	164
Copland, H. S.	Modern Roadway Construction	1878	61
Cornock, J. C.	Steam Wagons	1909	207
Cowper-Coles, S. O.	Protective Metallic Coatings for Iron and Steel.	1898	139
,, ,, ,,	The Electrolytic Treatment of Complex Sulphide Ores.	1899	203
,, ,, ,,	The Metallic Preservation and Ornamentation of Iron and Steel Surfaces.	1905	183
,, ,, ,,	Recent Storage Battery Improvements.	1906	201
Cox, S. H.	Recent Improvements in Tin-dressing Machinery.	1874	11
,, ,,	Dry Crushing Machinery	1892	101
,, ,,	President's Address	1896	1
Cramp, C. C.	Tramway Rolling-stock and Steam in connection therewith	1874	119
Crimp, W. S.	The Wimbledon Main Drainage and Sewage Disposal Works.	1888	73
,, ,,	Sewer Ventilation	1890	139
Croll, J.	Filter Presses for Sewage Sludge	1897	121
Crompton, E. S.	The Economics of Railway Maintenance.	1870	101
Cullen, Dr. E.	The Surveys of Proposed Lines for a Ship Canal between the Atlantic and Pacific Oceans.	1868	15
,, ,,	The Panama Railroad	1868	39
,, ,,	Isthmus of Darien and the Ship Canal.	1868	52
Cunningham, J. H.	Pin-connected *v.* Riveted Bridges	1889	135

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Danvers, F. C. ..	Engineering in India	1868	137
Davenport, J. G. ..	Wooden Jetties on the River Thames and their Improvement of the Inshore Navigation	1859	24
Davey, H.	Pumping Engines for Town Water Supply.	1867	88
,, ,, ...	Milford Haven and its New Pier Work.	1872	89
,, ,, ...	Recent Improvements in Pumping Engines for Mines.	1873	182
,, ,, ...	The Underground Pumping Machinery at the Erin Colliery, Westphalia.	1876	119
Day, St. J. V.	Recent Arrangements of Continuous Brakes.	1875	87
De Segundo, E. C.	Power Distribution by Electricity, Water and Gas.	1894	143
Digby, W. P.	Statistics of British and American Rolling Stock.	1905	49
Digby, W. P., and Shenton, H. C. H.	Prevention of the Bacterial Contamination of Streams and Oyster Beds.	1906	229
Drury, A. G.	The Shortlands and Nunhead Railway.	1892	219
Edwards, E.	Mining Machinery	1859	35
,, ,, ...	Utilisation of Waste Mineral Substances.	1861	82
Engert, A. C.	The Prevention of Smoke	1881	101
,, ,, ...	Defects of Steam Boilers and their Remedy.	1884	25
,, ,, ...	The Blow-pipe Flame Furnace ..	1884	185
Faija, H.	Portland Cement	1885	95
,, ,, ...	The Effect of Sea Water on Portland Cement.	1888	39
,, ,, ...	Forced Filtration of Water through Concrete.	1889	107
Faraday, P. M. ..	The Rating of Engineering Undertakings.	1897	43
Fell, J. C.	President's Address	1899	1
,, ,, ...	Soft *v.* Hard Water for Manufacturing Purposes.	1884	103
Ferrar, W. G. ..	Practical Construction in the Colonies.	1875	53
Fox, St. G. Lane ..	The Lighting and Extinction of Street Gas Lamps by Electricity	1878	105
Fox, W.	Reservoir Embankments	1898	23
Fox, W. H.	Continuous Railway Brakes ..	1872	112
,, ,, ...	Continuous Railway Brakes ..	1873	33
Fraser, A.	Use of the Cornish Pumping Engine	1864	78

Author.	Subject of Paper.	Transactions.	
		Year.	Page,
Galbraith, A. R.	The Hennébique System of Ferro-Concrete Construction.	1902	177
Gandon, C.	President's Address	1885	1
,, ,,	Gas Engines	1881	27
Gay, A.	Mechanical Stokers for Electricity Generating Stations.	1903	209
Gibbs, J. D.	The Distribution of Electrical Energy by Secondary Generators.	1885	49
Glynn, J., Jun.	Softening Water by Dr. Clarke's Process.	1859	29
,, ,,	The Chalk Formation	1860	46
Goodwin, G. A.	President's Address	1894	1
Gore, H.	Modern Gas Works at Home and Abroad.	1868	233
,, ,,	Horse Railways and Street Tramways.	1873	113
Grantham, R. F.	Sea Defences	1897	143
,, ,,	The Closing of Breaches in Sea and River Embankments.	1900	21
Greig, A.	Dundee Street Improvements and Drainage of Lochee.	1883	113
Gresham, J.	The most Recent Improvements on the Injector.	1867	266
Grierson, F. W.	The National Value of Cheap Patents.	1880	145
Grierson, T. B.	The Treatment of Low-grade Iron Ores for the Smelting Furnace.	1901	69
Griffin, S.	Modern Gas-engine Practice	1889	169
Griffith, P.	President's Address	1902	1
,, ,,	The Treatment and Utilisation of Exhaust Steam.	1890	163
,, ,,	The Water Supply of Small Towns and Rural Districts.	1896	55
Hakewill, H.	Circular Tables	1865	147
Haldwell, W. E.	The Sinlumkaba Bridge	1909	121
Hall, C. E.	The Conversion of Peat into Fuel and Charcoal.	1876	151
,, ,,	Modern Machinery for Preparing Macadam for Roads.	1879	51
Harman, E. A.	Gas-Works Machinery	1898	97
Harris, G.	Water Supply to Country Mansions and Estates.	1899	231
Hartley, F. W.	Methods employed in the Determination of the Commercial Value and the Purity of Coal Gas.	1869	100
,, ,,	An Improved Method of Charging and Drawing Gas Retorts.	1875	185
Healey, B. D.	The Economical Disposal of Town Refuse.	1900	65
,, ,,	Recent Blast Furnace Practice	1902	97
Henderson, R.	Paper-making Machinery	1900	139

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Hendry, J.	Pump Valves	1859	25
Hetherington, R. G.	The Main Drainage of Ilford	1901	173
Hollis, S. A.	Preliminary Investigations for Water Supply.	1901	147
Holttum, W. H.	The Use of Steel Needles in Driving a Tunnel at King's Cross.	1892	199
Hooper, H. R.	The Practice of Foundry Work	1888	191
Horner, J. G.	Certain Methods of Applying Screw Piles in a Bridge at Verona.	1867	52
Horsley, C.	President's Address	1881	1
Huggins, H. C.	Bridle-Roads in the West Indies	1907	193
Hutton, R. J.	The Stability of Chimney Shafts	1887	150
Jacob, A.	The Designing and Construction of Storage Reservoirs.	1866	225
Jensen, G. J. G.	Notes on Certain Details of Drainage Construction.	1901	19
Jensen, P.	Incrustation in Marine Boilers	1866	117
,, ,,	Friction in Steam Cylinders	1870	17
Jerram, G. B.	River Pollution caused by Sewage Disposal.	1886	217
Jones, A. W.	Modern Tramway Construction	1879	179
Justice, P. S.	The Dephosphorisation of Iron in the Puddling Furnace.	1885	189
Kerr, J.	Portable and Pioneer Railways	1891	89
Kershaw, J. T.	Breakwaters and Harbours of Refuge.	1859	31
,, ,,	The Pipe Sewers of Croydon and the Causes of their Failure.	1860	52
King, G.	Irrigation with Town Sewage	1865	84
Kinsey, W. B.	The Arrangement, Construction, and Machinery of Breweries.	1881	173
Knapp, H. F.	Harbour Bars: their Formation and Removal.	1878	139
Kochs, W. E.	Strength and Rigidity	1865	69
Lailey, C. N.	Acton Main Drainage Works	1888	125
Latham, B.	President's Address	1868	1
,, ,,	President's Address	1871	1
,, ,,	The Drainage of the Fens	1862	154
,, ,,	The Inundations of Marshland	1862	173
,, ,,	The Supply of Water to Towns	1864	199
,, ,,	Utilisation of Sewage	1866	68
,, ,,	The Application of Steam to the Cultivation of Soil.	1868	274
,, ,,	Ventilation of Sewers	1871	39
Latham, F.	Some Recent Works of Water Supply at Penzance.	1904	11
,, ,,	Harbour Exigency Works	1906	45

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
LAWFORD, G. M.	President's Address	1897	1
,, ,,	Fireproof Floors	1889	43
LAWFORD, G. M.	Drainage of Town Houses	1891	187
LAWFORD, W.	Light Railways	1888	161
LEE, J. B.	Photographic Surveying	1899	171
LE FEUVRE, W. H.	President's Address	1867	1
LE GRAND, A.	Tube Wells	1877	133
LEWES, V. B.	Gas Substitutes	1893	141
LIGHT, C. J.	Railway Switches and Crossings	1857	13
,, ,,	Railway Turntables	1858	11
,, ,,	The Permanent Way of Railways	1859	21
,, ,,	The Need of Further Experiments on the Strength of Materials.	1869	194
,, ,,	A new Method of Setting-out the Slopes of Earthworks.	1873	216
,, ,,	Opening Bridges on the Furness Railway.	1885	119
LIGHT, C. L.	Street Railways	1860	56
LIGHTFOOT, T. B.	Refrigerating Machinery on Board Ship.	1887	105
,, ,,	A Trial of a Refrigerating Machine on the Linde System.	1891	39
LOUCH, J.	Surface Condensers	1861	96
MACGEORGE, W.	President's Address	1874	1
MACKENZIE, D.	Motor Transport for Goods	1903	155
MAJOR, W.	The Priming of Steam-Boilers	1877	59
MARTIN, W.	The Strength of Flues in Lancashire and similar Boilers.	1882	157
MARTIN, W. A.	Induced *v.* Forced Draught for Marine Boilers.	1886	111
MASON, C.	President's Address	1901	1
,, ,,	Street Subways for Large Towns	1895	91
MATHESON, E	The Quality of Iron, as now used	1867	168
,, ,,	The Accumulator Cotton Press	1868	264
MATTHEWS, E. R.	Electric Light Stations, their design and arrangement.	1903	117
,, ,,	The Parade Extension Works at Bridlington.	1905	81
,, ,,	Waterworks Construction in America.	1907	77
,, ,,	Corrosion of Steel Reinforcement in Concrete.	1909	61
MAUDE, T.	The Government Brake Trials	1875	129
MAWBEY, E. G.	The Leicester Main Drainage	1893	25
MCNAUGHT, W.	The Rolling of Ships	1876	187
MEIK, C.S., & BEER, W.	The Improvement of London Traffic	1905	117
METCALFE, A. J.	The Treatment and Formation of Road Surfaces.	1908	25
MIDDLETON, R. E.	Relative Value of Percolation Gauges.	1895	153

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Middleton, R. E. . .	The Pollution of Water and its Correction.	1897	173
Miles, W. P.	Locks and Fastenings	1860	26
Miller, B. A.	The Cleansing and Ventilation of Pipe Sewers.	1892	167
Molesworth, G. L.	The Utilisation of Water Power . .	1858	16
Moore, C.A. St. Geo.	Working Experiences with Large Gas Engines.	1907	115
Moore, L. G.	The Explosion at Erith, and the Repair of the River Bank.	1864	183
Moore, R. St. Geo.	President's Address	1907	1
Morris, W.	The Machinery employed in Raising Water from an Artesian Well.	1860	29
Moultrie, F. R. . .	Photography	1857	12
Nursey, P. F.	President's Address	1886	1
,, ,, ...	Quartz Crushing Machinery . .	1860	17
,, ,, ...	The Chemical Extraction of Gold from its Ores.	1860	42
,, ,, ...	The Superheating of Steam, and the various Apparatus employed therein.	1861	36
,, ,, ...	Steam Boiler Explosions	1863	1
,, ,, ...	Fuel	1864	1
,, ,, ...	Sugar-making Machinery	1865	155
,, ,, ...	Explosive Compounds for Engineering Purposes.	1869	10
,, ,, ...	English and Continental Intercommunication.	1869	154
,, ,, ...	Recent Improvements in Explosive Compounds.	1871	108
,, ,, ...	Economic Uses of Blast Furnace Slag	1873	196
,, ,, ...	Mechanical Puddling	1874	77
,, ,, ...	The Channel Railway	1876	17
,, ,, ...	Illumination by means of Compressed Gas.	1881	57
,, ,, ...	Modern Bronze Alloys for Engineering Purposes.	1884	127
,, ,, ...	Primary Batteries for Illuminating Purposes.	1887	185
,, ,, ...	Recent Developments in High Explosives.	1889	71
,, ,, ...	Fox's Patent System of Solid-pressed Steel Waggon and Carriage Frames.	1889	197
,, ,, ...	Pick's System of Manufacturing Salt in Vacuo.	1890	115
,, ,, ...	Some Practical Examples of Blasting	1893	201
,, ,, ...	The Preparation of Rhea Fibre for Textile Purposes.	1898	177
,, ,, ...	The Production of Metallic Bars and Tubes under Pressure.	1901	45

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Nursey, P. F.	The Society's History: A Jubilee Retrospect.	1904	65
,, ,,	Recent Practice in Cane-Sugar Machinery.	1906	149
Oates, A.	The Utilisation of Tidal Energy	1882	81
O'Connor, H.	President's Address	1900	1
,, ,,	Machine Stokers for Gas Retorts	1891	117
,, ,,	Pile-Driving	1894	71
,, ,,	Automatic Gas Station Governors	1897	67
Olander, E.	The Enclosure of Lands from the Sea and the Construction of Sea and other Banks.	1862	25
,, ,,	Bridge Floors: Their Design, Strength, and Cost.	1887	27
Olrick, H.	A new System of Treating Sewage Matter.	1883	23
Olrick, L.	Marine Governors	1862	104
,, ,,	Giffard's Injector	1865	280
Ordish, R. M.	Suspension Bridges	1857	13
,, ,,	The Forms and Strengths of Beams Girders and Trusses.	1858	13
Owens, J. S.	A new Test for Concrete	1909	29
Page, G. G.	The Construction of Chelsea Bridge	1863	77
Parkes, M.	The Road Bridges of the Charing Cross Railway.	1864	143
,, ,,	The Charing Cross Railway Bridge over the Thames.	1864	166
Parsey, W.	Perspective	1859	26
,, ,,	Trussed Beams	1862	52
Paul, J. H.	Corrosion in Steam Boilers	1891	147
Pearse, J. W.	The Ventilation of Buildings	1876	97
,, ,,	The Mechanical Firing of Steam Boilers.	1877	31
,, ,,	Water Purification, Sanitary and Industrial.	1878	29
Pease, E. L.	Gasholder Construction	1894	95
Peirce, W. G.	President's Address	1895	1
Pendred, H. W.	Screw Propellers, their Shafts and Fittings.	1875	151
,, ,,	Distilling and Hoisting Machinery for Sea-going Vessels.	1880	55
,, ,,	Designs, Specifications, and Inspection of Ironwork	1883	87
Pendred, V.	President's Address	1876	1
,, ,,	Elastic Railway Wheels	1864	119
,, ,,	The Adhesion of Locomotive Engines, and certain Expedients for increasing or supplementing that Function.	1865	207
,, ,,	Water-tube Boilers	1867	109

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Pendred, V.	Apparatus for Measuring the Velocity of Ships.	1869	215
,, ,,	Examples of Recent Practice in American Locomotive Engineering.	1872	19
Perrett, E.	Filtration by Machinery	1888	106
Phillips, J.	The Forms and Construction of Channels for the Conveyance of Sewage.	1874	145
Pieper, C.	Ice-making Machinery	1882	139
Pollard-Urquhart, M. A.	Examples of Railway Bridges for Branch Lines.	1896	117
Ransom, H. B.	The Principles and Practice of Hydro-Extraction.	1894	227
Reade, S. A.	The Redhill Sewage Works	1868	168
Redman, J. B.	Tidal Approaches and Deep Water Entrances.	1885	143
Rigg, A.	President's Address	1884	1
,, ,,	The Connection between the Shape of heavy Guns and their Durability.	1867	249
,, ,,	The Screw Propeller	1868	202
,, ,,	Sensitiveness and Isochronism in Governors.	1880	73
,, ,,	American Engineering Enterprise	1885	21
,, ,,	Obscure Influences of Reciprocation in High-speed Engines.	1886	83
,, ,,	Balancing of High-speed Steam Engines.	1891	23
,, ,,	Hydraulic Rotative Engines	1896	89
Riley, E.	The Manufacture of Iron	1861	59
,, ,,	The Action of Peaty Water on a Boiler.	1862	45
Roberts, W.	Steam Fire-engines, and the late Trials at the Crystal Palace.	1863	163
Robertson, George	Mortars and Cements	1857	11
Robinson, H.	President's Address	1887	1
,, ,,	Sewage Disposal	1879	197
Roechling, H. A.	The Sewage Question during the last Century.	1901	193
Roots, J. D.	Petroleum Motor Vehicles	1899	95
Rous-Marten, C.	Notes on English and French Compound Locomotives.	1900	173
,, ,,	Notes on some Twentieth Century Locomotives.	1902	125
Rumble, T. W.	Armour Plates	1861	87
Rymer-Jones, T. M.	Railway Tunnelling in Japan	1882	101
Sanderson, C.	The Bombay, Baroda, and Central India Railway.	1863	97

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Schönheyder, W. ..	Equalising the Wear in Horizontal Steam Cylinders.	1878	45
Scott, H. C. D. ..	The Destruction of Arch Bridges	1908	61
Scott, P. G.	Notes on Railway Surveys and Design in New Countries.	1904	103
Sefi, M.	The Theory of Screw Propulsion ..	1870	82
Sellon, S.	Electrical Traction and its Financial Aspect.	1892	37
Sellon, S., and Beaumont, W. W.	Notes on Parliamentary Procedure as affecting Light Railways and Tramways.	1895	33
Shenton, H. C. H. ..	Recent Practice in Sewage Disposal	1900	217
,, ,, ..	The Latest Practice in Sewage Disposal.	1904	41
Shenton, H. C. H. and Digby, W. P.	Prevention of the Bacterial Contamination of Streams and Oyster Beds.	1906	229
Silcock, E. J.	President's Address	1909	1
Smith, A. H.	Machine Drills for Hard Rock ..	1905	155
Smith, Prof. R. H...	The Design and the Waste and Wear of Wheel Teeth.	1908	81
Somerville, J. ..	Charging and Drawing Gas Retorts by Machinery.	1873	138
Sommerville, D. ..	The Chemistry and Bacteriology of Potable Waters.	1906	67
,, ,, ..	The Chemistry and Bacteriology of Sewage Purification.	1909	175
Spencer, G.	State Railways and Railway Amalgamation.	1872	43
Spice, R. P.	President's Address	1878	1
,, ,, ...	President's Address	1879	1
,, ,, ...	Some Modern Improvements in the Manufacture of Coal Gas.	1886	131
Spon, E.	The Use of Paints as an Engineering Material.	1875	69
Standfield, J. ..	Floating Docks—the Depositing Dock, and the Double-power Dock.	1881	81
Stead, E. J.	The Connaught Bridge, Natal ..	1907	15
Steel, J.	Air Compression	1876	65
Stephenson, H. P.	Screw Piles	1857	12
Stephenson, W. H.	The General Structure of the Earth	1858	12
,, ,,	Fire-clay Manufactures	1861	17
Stocker, C. W. ..	Diving Apparatus	1860	32
Stopes, H.	The Engineering of Malting ..	1884	65
Storey, W. E. ..	Condensing Machinery	1904	197
Stow, J. F.	Irrigation Works in South Africa	1901	159
Strachan, G. R. ..	The Construction and Repair of Roads.	1889	17
Suckling, N. J. ..	Modern Systems of Generating Steam.	1874	39
Sugg, W. T.	Apparatus employed for Illumination with Coal Gas.	1869	134

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Sugg, W. T.	Ventilation and Warming	1895	235
Sutcliff, R.	Tube Wells for large Water Supplies.	1877	149
Tarbutt, P. F.	Liquid Fuel	1886	193
Thame, J.	Recent Developments in Crushing and Concentrating Machines.	1904	173
Thomas, G. A.	Status Prize Essay	1909	147
Thomas, H. B.	Subaqueous Operations	1907	213
Thomas, R. J.	Road Maintenance and Administration.	1903	49
Thorp, R. F.	The Renard and Sourcouf Road-train System.	1907	43
Thresh, J. C.	The Protection of Underground Water Supplies.	1898	47
Thrupp, E. C.	A New Formula for the Flow of Water in Pipes and Open Channels.	1887	224
Thudichum, G.	The Ultimate Purification of Sewage.	1896	199
,, ,,	Bacterial Treatment of Sewage	1898	207
,, ,,	The Bacterial Treatment of Sewage	1903	185
Thwaite, B. H.	British *v.* American Patent Law Practice.	1902	23
,, ,,	The Transport Possibilities of our Inland Navigable Waterways.	1905	19
,, ,,	The Renard and Sourcouf Road-train System.	1907	43
Trewman, H. C.	Flues and Ventilation	1876	91
Turner, C.	The Timbering of Trenches and Tunnels.	1871	90
Tweddell, R. H.	Direct-acting Hydraulic Machinery	1877	95
,, ,,	The Application of Water Pressure to Machine Tools and Appliances	1890	35
Umney, H	Safety Appliances for Elevators	1895	113
,, ,,	The Compression of Air by the Direct Action of Water.	1897	93
Usill, G. W.	Rural Sanitation	1877	113
Valon, W. A. M.	President's Address	1893	1
Varley, S. A.	Railway Train Intercommunication.	1873	162
Wagstaff, E. W.	The Shan Hill Country and the Mandalay Railway.	1899	21
Wales, W. G.	Discharging and Storing Grain	1896	149
Walker, J.	Brewing Apparatus	1871	29
Walmisley, A. T.	President's Address	1888	1

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Walmisley, A. T.	Iron Roofs	1881	123
Wanklyn, J. A.	Cooper's Coal-liming Process	1884	167
Ward, G. M.	The Utilisation of Coal Slack in the Manufacture of Coke for Smelting.	1880	33
Ware, W. J., and Woodhead, G. S.	Disinfection of the Maidstone Water Service Mains.	1900	49
Warren, A.	Steam Navigation on the Indus	1863	139
Wesseley, C. R. von.	Arched Roofs	1866	36
West, N. J.	President's Address	1905	1
Wilkins, T.	The Machinery and Utensils of a Brewery.	1871	10
Willcock, J.	Gas Meters and Pressure Gauges	1860	37
Wilson, A. F.	The Manufacture of Coal Gas	1864	35
Wilson, J. W.	The Construction of Modern Piers	1875	29
,, ,,	President's Address	1892	1
,, ,,	President's Address	1908	1
Wilson, M.	President's Address	1906	1
Wise, F.	Signalling for Land or Naval Purposes.	1863	117
Wise, W. L.	The Patent Laws	1870	45
Wollheim, A.	Foreign Sewage Precipitation Works.	1892	123
Woodhead, G. S., and Ware, W. J.	Disinfection of the Maidstone Water Service Mains.	1900	49
Worssam, S. W.	Mechanical Saws	1867	196
Yarrow, A. F.	Steam Carriages	1862	128
Young, C. F. T.	The Use of Coal in Furnaces without Smoke.	1862	66

SUBJECTS.

Subject of Paper.	Author.	Transactions. Year.	Transactions. Page.
Accumulator Cotton Press	E. Matheson	1868	264
Action of Marine Worms and Remedies employed in Harbour of San Francisco.	J. Blackbourn ..	1874	111
Action of Peaty Water on a Boiler	E. Riley	1862	45
Acton Main Drainage Works ..	C. N. Lailey	1888	125
Address of President	W. T. Carrington ..	1865	1
,, ,, ...	Z. Colburn	1866	1
,, ,, ...	W. H. Le Feuvre ..	1867	1
,, ,, ...	B. Latham	1868	1
,, ,, ...	F. W. Bryant.. ..	1869	1
,, ,, ...	W. Adams	1870	1
,, ,, ...	B. Latham	1871	1
,, ,, ...	J. Church	1872	1
,, ,, ...	,, ,, ...	1873	1
,, ,, ...	W. Macgeorge ..	1874	1
,, ,, ...	J. H. Adams	1875	1
,, ,, ...	V. Pendred	1876	1
,, ,, ...	T. Cargill	1877	1
,, ,, ...	R. P. Spice	1878	1
,, ,, ...	,, ,, ...	1879	1
,, ,, ...	J. Bernays	1880	1
,, ,, ...	C. Horsley	1881	1
,, ,, ...	J. Church	1882	1
,, ,, ...	,, ,, ...	1883	1
,, ,, ...	A. Rigg	1884	1
,, ,, ...	C. Gandon	1885	1
,, ,, ...	P. F. Nursey	1886	1
,, ,, ...	Prof. H. Robinson..	1887	1
,, ,, ...	A. T. Walmisley ..	1888	1
,, ,, ...	J. R. Baillie	1889	1
,, ,, ...	H. Adams	1890	1
,, ,, ...	W. N. Colam	1891	1
,, ,, ...	J. W. Wilson	1892	1
,, ,, ...	W. A. M. Valon ..	1893	1
,, ,, ...	G. A. Goodwin ..	1894	1
,, ,, ...	W. G. Peirce	1895	1
,, ,, ...	S. H. Cox	1896	1
,, ,, ...	G. M. Lawford ..	1897	1
,, ,, ...	W. W. Beaumont ..	1898	1
,, ,, ...	J. C. Fell	1899	1
,, ,, ...	H. O'Connor	1900	1
,, ,, ...	C. Mason	1901	1
,, ,, ...	P. Griffith	1902	1
,, ,, ...	J. P. Barber	1903	1
,, ,, ...	D. B. Butler	1904	1
,, ,, ...	N. J. West	1905	1
,, ...	M. Wilson	1906	1

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Address of President	R. St. George Moore	1907	1
,, ,,	J. W. Wilson	1908	1
,, ,,	E. J. Silcock	1909	1
Adhesion of Locomotive Engines and certain Expedients for Increasing or Supplementing that Function.	V. Pendred	1865	207
Admixtures of Kentish Ragstone, &c., upon Portland Cement, The Effect of	D. B. Butler	1896	179
Air Compression	J. Steel	1876	65
Air, Compression of, by the Direct Action of Water, The	H. W. Umney	1897	93
American Engineering Enterprise	A. Rigg	1885	21
American Locomotive Engineering, Examples of Recent Practice in	V. Pendred	1872	19
Annual General Meeting		1902	305
,, ,, ,,		1903	234
,, ,, ,,		1904	231
,, ,, ,,		1905	232
,, ,, ,,		1906	277
,, ,, ,,		1907	249
,, ,, ,,		1908	283
Annual Report of Council		1902	309
,, ,, ,,		1903	235
,, ,, ,,		1904	232
,, ,, ,,		1905	233
,, ,, ,,		1906	278
,, ,, ,,		1907	250
,, ,, ,,		1908	284
,, ,, ,,		1909	247
Apparatus for utilising the Waste Heat of Exhaust Steam	J. Atkinson	1878	167
Apparatus for Measuring the Velocity of Ships.	V. Pendred	1869	15
Apparatus employed for Illumination with Coal Gas.	W. Sugg	1869	134
Application of Electricity to Hoisting Machinery.	R. Bolton	1892	79
Application of Steam to the Cultivation of the Soil.	B. Latham	1868	274
Application of Water Pressure to Machine Tools and Appliances.	R. H. Tweddell	1890	35
Arched Roofs	C. von Wesseley	1866	36
Armour Plates	T. W. Rumble	1861	87
Arrangement, Construction, and Machinery of Breweries.	W. B. Kinsey	1881	173
Artesian Well, The Machinery employed in raising Water from an	W. Morris	1860	29
Atlantic Cable, The Machinery employed in laying the	J. Amos	1858	13
Australian Timber Bridges	H. E. Bellamy	1902	63
Automatic Gas Station Governors	H. O'Connor	1897	67

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Axles, The Strength of Wrought-iron Railway	T. Andrews	1879	143
Bacterial Contamination of Streams and Oyster Beds, Prevention of the	W. P. Digby and H. C. H. Shenton	1906	222
Bacterial Treatment of Sewage	G. Thudichum	1898	207
Bacterial Treatment of Sewage, The	,, ,,	1903	185
Bars and Tubes, The Production of Metallic, under Pressure.	P. F. Nursey	1901	45
Batteries, Primary, for Illuminating Purposes.	,, ,,	1887	185
Beams, Girders and Trusses, The Forms and Strengths of	R. M. Ordish	1858	13
Blake's Bridge, Reading	E. Burrows	1893	71
Blast Furnace Practice, Recent	B. D. Healey	1902	97
Blast-furnace Slag, The Economic Uses of	E. Burrows	1873	196
Blasting Charges, The Application of Electricity to the Ignition of	G. G. André	1878	123
Blasting, Some Practical Examples of	P. F. Nursey	1893	201
Blow-pipe Flame Furnace	A. C. Engert	1884	185
Boilers, Incrustation in Marine	P. Jensen	1866	117
Boilers, Strength of Flues in Lancashire and similar	W. Martin	1882	157
Boilers, The Defects of Steam, and their Remedy.	A. C. Engert	1884	25
Boilers, The Mechanical Firing of Steam	J. W. Pearse	1877	31
Boilers, The Priming of Steam	W. Major	1877	59
Boilers, Water and its Effects on Steam	H. K. Bamber	1867	65
Boilers, Water Tube	V. Pendred	1867	109
Bombay, Baroda, and Central India Railway.	C. Sanderson	1863	97
Brake Trials, The Government	T. Maude	1875	129
Brakes, Continuous Railway	W. H. Fox	1872	112
,, ,, ,,	,, ,,	1873	33
Brakes, Hydraulic Continuous and Automatic	E. D. Barker	1879	75
Brakes, Recent Arrangements of Continuous	St. J. V. Day	1875	87
Breaches in Sea and River Embankments, The Closing of	R. F Grantham	1900	21
Breakwater Construction	F. H. Cheesewright	1890	83
Breakwaters and Harbours of Refuge	J. T. Kershaw	1859	31
Breakwaters, Floating	T. Cargill	1871	146
Breweries, the Arrangement, Construction, and Machinery of	W. B. Kinsey	1881	173
Brewery, Machinery and Utensils of a	T. Wilkins	1871	10
Brewery Apparatus	J. Walker	1871	29
Bridge, Blake's, Reading	E. Burrows	1893	71

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Bridge, Railway, at the Place de l'Europe, Paris.	T. Cargill	1866	191
Bridge Floors: Their Design, Strength and Cost.	E. Olander	1887	27
Bridge, The Connaught, Natal ..	E. J. Stead	1907	15
Bridge, Construction of Chelsea ..	G. G. Page	1863	77
Bridge over the Thames, Charing Cross Railway	M. Parkes	1864	166
Bridge, The Sinlumkaba	W. E. Haldwell ..	1909	121
Bridges, The Destruction of Arch ..	H. C. D. Scott ..	1908	61
Bridges of the Charing Cross Railway, The Road	M. Parkes	1864	143
Bridges, Opening, on Furness Railway.	C. J. Light	1885	119
Bridges, The Strength of Suspension	C. E. Browning ..	1858	11
Bridges, Suspension	R. M. Ordish	1857	13
Bridlington Parade Extension Works	E. R. Matthews ..	1905	81
British and American Coal Cutting Machines.	A. S. E. Ackermann	1904	71
British *v.* American Patent Law Practice.	B. H. Thwaite ..	1902	23
Bronze Alloys for Engineering Purposes, Modern	P. F. Nursey	1884	127
Buildings, The Ventilation of ..	J. W. Pearse	1876	97
Cable Tramways	W. N. Colam	1885	69
Caissons, Ship, for Dock Basins and Dry Docks.	J. J. F. Andrews ..	1890	189
Canadian System, A deep Boring near Freistadt, Austria, by the	R. N. Boyd	1894	119
Canal between the Atlantic and Pacific Oceans, The Surveys of Proposed Lines for a Ship	Dr. E. Cullen	1868	15
Canal, The Isthmus of Darien and the Ship	,, ,, ..	1868	52
Cane - Sugar Machinery, Recent Practice in	P. F. Nursey	1906	149
Carriage Frames, Fox's Patent System of Solid-pressed Steel Waggon and	,, ,, ...	1889	197
Carriages, Steam	A. F. Yarrow	1862	128
Case System of Groyning, Foreshore Protection, with special reference to the	R. G. Allanson-Winn	1899	133
Cast-Iron, Certain Methods of Treating, in the Foundry.	Z. Colburn	1865	77
Cement, Portland	H. Faija	1885	95
Cement Tests now in Vogue, Certain Vexatious and Fallacious	D. B. Butler	1903	89
Cements, Mortars and	G. Robertson	1857	11
Central India Railway, Bombay, Baroda, and	C. Sanderson	1863	97

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Chain Cable Groynes, Submerged	R. G. Allanson-Winn	1906	13
Chalk Formation, The	J. Glynn, jun	1860	46
Channel Railway, The	P. F. Nursey	1876	17
Channels for the Conveyance of Sewage, The Forms and Construction of	J. Phillips	1874	145
Charcoal, The Conversion of Peat into Fuel and	C. E. Hall	1876	151
Charging and Drawing Gas Retorts by Machinery	J. Somerville	1873	138
Charging and Drawing Gas Retorts, An Improved Method of	F. W. Hartley	1875	185
Charing Cross Railway Bridge over the Thames.	M. Parkes	1864	166
Charing Cross Railway, The Road Bridges of	,, ,,	1864	143
Cheap Patents, The National Value of	F. W. Grierson	1880	145
Chelsea Bridge, The Construction of	G. G. Page	1863	77
Chemistry and Bacteriology of Potable Waters, The	D. Sommerville	1906	67
Chimney Shafts, Stability of	R. J. Hutton	1887	150
Circular Tables	H. Hakewill	1865	147
Cleansing and Ventilation of Pipe Sewers.	B. A. Miller	1892	167
Cleaning of Tramway and other Rails.	H. Conradi	1893	47
Coal Cutting Machines, British and American	A. S. E. Ackermann	1904	71
Coal Gas, The Methods employed in the determination of the Commercial Value and Purity of	F. W. Hartley	1869	106
Coal Gas, Apparatus employed for illumination with	W. Sugg	1869	134
Coal Gas, The Manufacture of	A. F. Wilson	1864	35
Coal Gas, Modern Manufacture of	C. C. Carpenter	1891	61
Coal Gas, Some Modern Improvements in the Manufacture of	R. P. Spice	1886	131
Coal-liming Process, Cooper's	J. A. Wanklyn	1884	167
Coal Mines, The Ventilation of	G. André	1874	23
Coal Slack, Utilisation of, in the Manufacture of Coke for Smelting.	G. M. Ward	1880	33
Coffer Dams, Piling and	F. W. Bryant	1859	38
Collieries and Colliery Engineering	R. N. Boyd	1893	169
Colliery, The Underground Pumping Machinery at the Erin, Westphalia.	H. Davey	1876	119
Colonies, Practical Construction in the	W. G. Ferrar	1875	53
Compressed Gas, Illumination by means of	P. F. Nursey	1881	57
Compression, Air	J. Steel	1876	65

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Compression of Air by the Direct Action of Water, The	H. W. Umney	1897	93
Concrete, A new Test for	J. S. Owens	1909	29
Concrete, Corrosion of Steel Reinforcement in	E. R. Matthews	1909	61
Concrete, Forced Filtration of Water Through	H. Faija	1889	107
Concrete Subways for Underground Pipes	A. T. Allen	1901	99
Condensers, Surface	J. Louch	1861	96
Condensing Machinery	W. E. Storey	1904	197
Connection between the Shape of Heavy Guns and their Durability.	A. Rigg	1867	249
Construction, The, and Repair of Roads.	G. R. Strachan	1889	17
Construction, Modern Tramway	A. W. Jones	1879	79
Construction, Modern Roadway	H. S. Copland	1878	61
Construction of Chelsea Bridge	G. G. Page	1863	77
Construction of Modern Piers	J. W. Wilson	1875	29
Continental Intercommunication, English and	P. F. Nursey	1869	154
Continuous and Automatic Brakes, Hydraulic	E. D. Barker	1879	75
Continuous Brakes, Recent arrangements of	St. J. V. Day	1875	87
Continuous Railway Brakes	W. H. Fox	1872	112
,, ,, ,,	,, ,,	1873	33
Conversion of Peat into Fuel and Charcoal	C. E. Hall	1876	151
Cooper's Coal-liming Process	J. A. Wanklyn	1884	167
Cornish Pumping Engine, The Use of the	A. Fraser	1864	78
Corrosion in Steam Boilers	J. H. Paul	1891	147
Cotton Press, The Accumulator	E. Matheson	1868	264
Country Mansions and Estates, Water Supply to	G. Harris	1899	231
Crushing and Concentrating Machines, Recent Developments in	J. Thame	1904	173
Crushing, Dry, Machinery	S. H. Cox	1892	101
Cylinders, Equalising the Wear in Horizontal Steam	W. Schönheyder	1878	45
Cylinders, Friction in Steam	P. Jensen	1870	17
Cyprus, Engineering Notes on	C. J. Alford	1880	131
Darien and the Ship Canal, The Isthmus of	Dr. E. Cullen	1868	52
Deep Boring near Freistadt, Austria, by the Canadian System.	R. N. Boyd	1894	119
Deep-Sea Erosion and Foreshore Protection.	R. G. Allanson-Winn	1904	141
Deep-Sea Lighthouses, Feasibility and Construction of	C. Anderson	1883	45

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Deep-water Entrances, Tidal Approaches and	J. B. Redman	1885	143
Defects of Steam Boilers and their Remedy.	A. C. Engert	1884	25
Dephosphorisation of Iron in the Puddling Furnace	P. S. Justice	1885	169
Depreciation of Plant and Works under Municipal and Company Management.	C. H. W. Biggs	1902	271
Design, Strength and Cost of Bridge Floors.	E. Olander	1887	27
Designing and Construction of Storage Reservoirs, The	A. Jacob	1866	225
Designs, Specifications, and Inspection of Ironwork.	H. W. Pendred	1883	87
Destruction of Arch Bridges	H. C. D. Scott	1908	61
Direct-acting Hydraulic Machinery	R. H. Tweddell	1877	95
Direct-acting Pumping Engines	P. B. Björling	1877	79
Discharging and Storing Grain	W. G. Wales	1896	149
Disinfection of the Maidstone Water Service Mains	G.S.Woodhead and W. J. Ware	1900	49
Disposal of Sewage, The	H. Robinson	1879	197
Distilling and Hoisting Machinery for Sea-going Vessels.	H. W. Pendred	1880	55
Distribution of Electrical Energy by Secondary Generators.	J. D. Gibbs	1885	49
Diving Apparatus	C. W. Stocker	1860	32
Dock Basins and Dry Docks, Ship Caissons for	J. J. F. Andrews	1890	189
Docks, Floating—The Depositing Dock and the Double-power Dock.	J. Standfield	1881	81
Drainage and Water Supply to the Town of Fareham.	T. Buckham	1869	41
Drainage Construction, Notes on Certain Details of	G. J. G. Jensen	1901	19
Drainage of Town Houses	G. M. Lawford	1891	187
Drainage Works, Main, Acton	C. N. Lailey	1888	125
Drainage of the Fens, The	B. Latham	1862	154
Drills for Hard Rock, Machine	A. H. Smith	1905	155
Dry Crushing Machinery	S. H. Cox	1892	101
Dundee Street Improvements and Drainage of Lochee.	A. Greig	1883	113
Earth, The General Structure of	W. H. Stephenson	1858	12
Earthworks, A New Method of Setting out the Slopes of	C. J. Light	1873	216
Economics of Railway Maintenance	E. S. Crompton	1870	101
Economic Uses of Blast Furnace Slag.	P. F. Nursey	1873	196
Effect of Sea Water on Portland Cement.	H. Faija	1888	39

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Effect of Strain on Railway Axles, and the Minimum Flexion Resistance-Point in Axles, The	T. Andrews	1895	181
Elastic Railway Wheels	V. Pendred	1864	119
Electric Light Engineering, Notes on	C.H.W. Biggs and W. W. Beaumont	1882	23
Electric Light Stations, their Design and Arrangement.	E. R. Matthews ..	1903	117
Electric Telegraph, The	W. Ansell	1857	11
Electric Telegraph Instruments ..	E. G. Bartholomew	1872	53
Electric Telegraphy, irrespective of Telegraphic Apparatus.	,, ,,	1869	55
Electric Traction, Notes on	A. H. Binyon ..	1900	103
Electrical Batteries	,, ,, ...	1872	77
Electrical Energy, Distribution of, by Secondary Generators.	J. D. Gibbs	1885	49
Electrical Traction, and its Financial Aspect.	S. Sellon	1892	37
Electricity Generating Stations, Mechanical Stokers for	A. Gay	1903	209
Electricity, the Application of, to Hoisting Machinery.	R. Bolton	1892	79
Electricity, The application of, to the Ignition of Blasting Charges.	G. G. André	1878	123
Electricity, The Lighting and Extinction of Street Gas Lamps by	St. G. Lane Fox ..	1878	105
Electricity, Water and Gas, Power Distribution by	E. C. de Segundo ..	1894	143
Electrolytic Treatment of Complex Sulphide Ores.	S. O. Cowper-Coles	1899	203
Elevators, Safety Appliances for ..	H. W. Umney ..	1895	113
Embankments, Reservoir	W. Fox	1898	23
Embankments, The Closing of Breaches in Sea and River	R. F. Grantham ..	1900	21
Enclosure of Lands from the Sea, and the Construction of Sea and other banks.	E. Olander	1862	25
Engineering, Collieries and Colliery	R. N. Boyd	1893	169
Engineering Enterprise, American	A. Rigg	1885	21
Engineering Notes on Cyprus ..	C. J. Alford	1880	131
Engineering in India	F. C. Danvers.. ..	1868	137
Engineering of Malting	H. Stopes	1884	65
Engines, Direct-acting Pumping ..	P. B. Björling ..	1877	79
Engines for Mines, Recent Improvements in Pumping	H. Davey	1873	182
Engines for Town Water Supply, Pumping	,, ,, ...	1867	88
Engines, Gas	C. Gandon	1881	27
Engines, Hydraulic Rotative ..	A. Rigg	1896	89
Engines, Obscure influences of reciprocation in High Speed	,, ...	1886	83

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Engines on the Rimutakai Incline, New Zealand, The Fell	R. J. Alford	1882	121
Engines, Pumping	W. T. Carrington ..	1859	19
Engines, Steam Fire, and the late trial at the Crystal Palace.	W. Roberts	1863	163
Engines, The Adhesion of Locomotive, and certain Expedients for increasing or supplementing that Function.	V. Pendred	1865	207
Engines, Use of the Cornish Pumping	A. Fraser..	1864	78
English and Continental Intercommunication.	P. F. Nursey	1869	154
English and French Compound Locomotives, Notes on	C. Rous-Martin ..	1900	173
Equalising the Wear in Horizontal Steam Cylinders.	W. Schönheyder ..	1878	45
Examples of Railway Bridges for Branch Lines.	M. A. Pollard-Urquhart	1896	117
Examples of Recent Practice in American Locomotive Engineering.	V. Pendred	1872	19
Exhaust Steam, Apparatus for Utilising the Waste Heat of	J. Atkinson	1878	167
Exhaust Steam, Treatment and Utilisation of	P. Griffith	1890	163
Exhibitions as Aids to Engineering Progress, Value of the	S. Barnett	1883	75
Experimental Researches into the Nature and Action of Steam Boilers.	T. Baldwin	1867	23
Experiments on the Strength of Materials, The Need of further	C. J. Light	1869	194
Explosion at Erith, and the Repair of the River Bank.	L. G. Moore	1864	183
Explosions, Steam Boiler	P. F. Nursey	1863	1
Explosive Compounds for Engineering Purposes.	,, ,, ...	1869	10
Explosive Compounds, Recent Improvements in	,, ,, ...	1871	108
Explosives, High, Recent Developments.	,, ,, ...	1889	75
Extension and Permanent Set of Wrought Iron, The	C. E. Browning ..	1858	15
Extraction of Gold, The Chemical	P. F. Nursey	1860	42
Fareham, Drainage and Water Supply of the Town of	T. Buckham	1869	41
Feasibility and Construction of Deep-sea Lighthouses.	C. Anderson	1883	45
Fell Engines on the Rimutakai Incline, New Zealand.	R. J. Alford	1882	121

Subject of Paper.	Author.	Transactions. Year.	Transactions. Page.
Fens, The Drainage of the	B. Latham	1862	154
Ferro-Concrete Construction, The Hennébique System of	A. R. Galbraith ..	1902	177
Filter Presses for Sewage Sludge ..	J. Croll	1897	121
Filtration by Machinery	E. Perrett	1888	106
Filtration, Forced, of Water through Concrete	H. Faija	1889	107
Fire-clay Manufactures	W. H. Stevenson ..	1861	17
Fire Engines, Steam	W. Roberts	1863	163
Fireproof Floors	G. M. Lawford ..	1889	43
Floating Breakwaters	T. Cargill	1871	146
Floating Docks: The Depositing Dock and the Double-power Dock.	J. Standfield	1881	81
Floors, Fireproof	G. M. Lawford ..	1889	43
Flow of Water, New Formula for, in Pipes and Open Channels.	E. C. Thrupp	1887	224
Flues and Ventilation	A. H. C. Trewman ..	1876	91
Flues in Lancashire and similar Boilers, The Strength of	W. Martin	1882	157
Flow of Liquid Fuel through Carburettor Nozzles.	R. W. A. Brewer ..	1908	197
Foreign Sewage Precipitation Works	A. Wollheim	1892	123
Foreshore Protection, with special reference to the Case System of Groyning.	R. G. Allanson-Winn	1899	133
Foreshore Protection, Deep-Sea Erosion and	,, ,,	1904	141
Forms and Construction of Channels for the Conveyance of Sewage.	J. Phillips	1874	145
Forms and Strengths of Beams, Girders and Trusses, The	R. M. Ordish	1858	13
Foundry Work, Practice of	H. R. Hooper	1888	191
Fox's Patent System of Solid-pressed Steel Waggon and Carriage Frames.	P. F. Nursey	1889	197
Friction in Steam Cylinders	P. Jensen	1870	17
Friction of the Slide Valve and its Appendages.	T. Adams	1866	6
Fuel	P. F. Nursey	1864	1
Fuel and Charcoal, The Conversion of Peat into	C. E. Hall	1876	151
Fuel, Liquid	P. F. Tarbutt	1886	193
Fuels, Liquid, for Internal Combustion Engines.	R. W. A. Brewer ..	1907	185
Furnace, The Blowpipe Flame ..	A. C. Engert	1884	134
Gas, Apparatus employed for Illumination with Coal	W. Sugg	1869	158
Gas-Engine, Modern, Practice ..	S. Griffin	1889	169
Gas Engines	C. Gandon	1881	27

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Gas-Engines, Working Experience of	C. A. St. Geo. Moore	1907	115
Gasholder Construction	E. L. Pease	1894	95
Gas, Illumination by means of Compressed	P. F. Nursey	1881	57
Gas Meters and Pressure Gauges ..	J. Willcock	1860	37
Gas, Modern Improvements in the Manufacture of Coal	R. P. Spice	1886	131
Gas Retorts, An Improved Method of Charging and Drawing	F. W. Hartley ..	1875	185
Gas Retorts, Charging and Drawing by Machinery.	J. Somerville	1873	138
Gas Retorts, Machine Stokers for	H. O'Connor	1891	117
Gas Station Governors, Automatic	,, ,, ...	1897	67
Gas Substitutes	V. B. Lewes	1893	141
Gas, The Manufacture of Coal ..	A. F. Wilson	1864	35
Gas, The Methods employed in the determination of the Commercial Value and Purity of Coal	F. W. Hartley ..	1869	100
Gas and Water Mains, The Prevention of Leakage in	C. M. Barker	1869	79
Gas Works at Home and Abroad, Modern	H. Gore	1868	233
Gas Works Machinery	E. A. Harman ..	1898	97
General Structure of the Earth, The	W. H. Stephenson ..	1858	12
Generation and Expansion of Steam	W. T. Carrington ..	1858	15
Giffard's Injector	L. Olrick	1865	280
Gold, The Chemical Extraction of ..	P. F. Nursey	1860	42
Government Brake Trials	T. Maude	1875	129
Governors, Marine	L. Olrick	1862	104
Governors, Sensitiveness and Isochronism in	A. Rigg	1880	73
Grain, Discharging and Storing ..	W. G. Wales	1896	149
Grindleford Stone Quarries and their Working.	B. L. Bradley ..	1905	201
Groyning, Submarine	G. O. Case	1906	107
Guns, The connection between the Shape of Heavy, and their Durability.	A. Rigg	1867	249
Harbour Bars : their Formation and Removal.	H. F. Knapp	1878	139
Harbour Exigency Works	F. Latham	1906	45
Harbours of Refuge, Breakwaters and	J. T. Kershaw ..	1859	31
Hauling Machinery, The new Pit and, for the San Domingos Mine in Portugal.	J. Bernays	1879	29
Hennébique System of Ferro-Concrete Construction, The	A. R. Galbraith ..	1902	177

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
High Pressure Steam and Steam Engine Efficiency.	W. W. Beaumont ..	1888	221
Hoisting Machinery, The Application of Electricity to	R. Bolton	1892	79
Horse Haulage, the Mechanics of ..	T. H. Brigg	1896	21
Horse Railways and Street Tramways.	H. Gore	1873	113
House Drainage, Notes on the Proposed By-laws of the London County Council with respect to	J. P. Barber	1897	17
Houses, Town, Drainage of	G. M. Lawford ..	1891	187
Hydraulic Continuous and Automatic Brakes	E. D. Barker	1879	75
Hydraulic Experiments, the Roorkee	E. S. Bellasis	1886	41
Hydraulic Lifts	R. Carey	1893	101
Hydraulic Machinery, Direct-acting	R. H. Tweddell ..	1877	95
Hydraulic Machinery for lifting Vessels in the Thames Graving Dock, The New	J. Amos	1859	17
Hydraulic Rotative Engines	A. Rigg	1896	89
Hydro-extraction, The Principles and Practice of	H. B. Ransom ..	1894	227
Ice-making Machinery	C. Pieper..	1882	139
Ignition of Blasting Charges, The application of Electricity to	G. G. André	1878	123
Ilford, The Main Drainage of.. ..	R. G. Hetherington	1901	173
Illumination by means of Compressed Gas.	P. F. Nursey	1881	57
Illumination with Coal Gas, Apparatus employed for	W. Sugg	1869	134
Improved Method of Charging and Drawing Gas Retorts.	F. W. Hartley ..	1875	185
Improvement of London Traffic ..	C. S. Meik and W. Beer	1905	117
Improvements in Explosive Compounds, Recent	P. F. Nursey	1871	108
Improvements in Pumping-engines for Mines, Recent	H. Davey	1873	182
Improvements in Tin Dressing Machinery, Recent	S. H. Cox	1874	11
Incrustation in Marine Boilers ..	P. Jensen	1866	117
India, Engineering in	F. C. Danvers ..	1868	137
Induced *v.* Forced Draught for Marine Boilers.	W. A. Martin	1886	111
Indus, Steam Navigation on the ..	A. Warren	1863	139
Injector, Giffard's	L. Olrick	1865	280
Injector, The most Recent Improvements on the	J. Gresham	1867	266

Subject of Paper.	Author.	Transactions. Year.	Transactions. Page.
Instruments, Electric Telegraph ..	E. G. Bartholomew	1872	53
Insurance, Marine	G. W. Allan	1858	14
Intercommunication, English and Continental	P. F. Nursey	1869	154
Intercommunication, Railway Train	S. A. Varley	1873	162
International System of Marine Course Signalling.	Capt. W. B. Barker	1884	47
Inundations of Marshland	B. Latham	1862	173
Iron Ores, The Treatment of Low-Grade, for the Smelting Furnace.	T. B. Grierson ..	1901	69
Iron, The Dephosphorisation of, in the Puddling Furnace.	P. S. Justice	5885	169
Iron, The Manufacture of	E. Riley	1861	59
Iron, The Relation between the Safe Load and ultimate Strength of	Z. Colburn	1863	35
Iron, The Quality of, as now used..	E. Matheson	1867	168
Iron Roofs	A. T. Walmisley ..	1881	123
Iron and Steel, Protective Metallic Coatings for	S. O. Cowper-Coles	1898	139
Iron and Steel Surfaces, The Metallic Preservation and Ornamentation of	,, ,, ...	1905	183
Iron and Steel Surfaces, The Preservation and Ornamentaion of	G. Bower	1883	59
Ironwork, Designs, Specifications, and Inspection of	H. W. Pendred ..	1883	87
Irrigation with Town Sewage ..	G. King	1865	84
Irrigation Works in South Africa ..	J. F. Stow	1901	159
Isochronism in Governors, Sensitiveness and	A. Rigg	1880	73
Isthmus of Darien and the Ship Canal.	Dr. E. Cullen	1868	52
Japan, Railway Tunnelling in ..	T. M. Rymer-Jones	1882	101
Joints. Single and Double-riveted	T. Baldwin	1866	150
Jubilee Retrospect, A: The Society's History.	P. F. Nursey	1904	65
Land and Naval Purposes, Signalling for	F. Wise	1863	117
Lartigue Single-rail Railway, The..	F. B. Behr	1886	163
Laws, Decrees and Regulations relating to Mining Operations in the old Kingdom of Sardinia.	C. J. Alford	1879	106
Leakage in Gas and Water Mains, The prevention of	C. M. Barker	1869	79
Leicester Main Drainage, The ..	E. G. Mawbey ..	1893	25

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Lifts, Hydraulic	R. Carey	1893	101
Light Railways	W. Lawford	1888	161
Light Railways and Tramways, Parliamentary Procedure as affecting	W. W. Beaumont and S. Sellon	1895	33
Lighthouses, The feasibility and construction of Deep-sea	C. Anderson	1883	45
Lighting and Extinction of Street Gas Lamps by Electricity.	St. G. Lane Fox ..	1878	105
Linde System, Trial of a Refrigerating Machine on the	T. B. Lightfoot ..	1891	39
Liquid Fuel	P. F. Tarbutt ..	1886	193
Liquid Fuel, flow of, through Carburettor Nozzles	R. W. A. Brewer ..	1908	197
Lochee, Dundee Street Improvements and Drainage of	A. Greig	1883	113
Locks and Fastenings	W. P. Miles	1860	26
Locomotive Engineering, Examples of recent Practice in American	V. Pendred	1872	19
Locomotive Engines, The adhesion of	,, ,, ...	1865	207
Locomotives, English and French Compound, Notes on	C. Rous-Marten ..	1900	173
Locomotives, Notes on some Twentieth Century	,, ,, ...	1902	125
London Traffic, The Improvement of	C. S. Meik and W. Beer	1905	117
Macadam for Roads, Modern Machinery for preparing	C. E. Hall	1879	51
Machine Drills for Hard Rock ..	A. H. Smith	1905	155
Machine, Refrigerating, on the Linde System, Trial of	T. B. Lightfoot ..	1891	39
Machinery, Dry, Crushing	S. H. Cox	1892	101
Machinery, Refrigerating, on Board Ship	T. B. Lightfoot ..	1887	105
Machinery, Filtration by	E. Perrett	1888	106
Machinery and Utensils of a Brewery	T. Wilkins	1871	10
Machinery, Gas Works	E. A. Harman ..	1898	97
Machinery, Quartz Crushing	P. F. Nursey	1860	17
Machine Stokers for Gas Retorts ..	H. O'Connor	1891	117
Machine Tools	E. C. Amos	1899	51
Machine Tools and Appliances, application of Water Pressure to	R. H. Tweddell ..	1890	35
Machinery employed in laying the Atlantic Cable, The	J. Amos	1858	13
Machinery employed in raising Water from an Artesian Well, The	W. Morris	1860	29
Machinery, Mining	E. Edwards	1859	35
Machinery, Paper-Making	R. Henderson	1900	139
Machinery, Weighing, and Automatic Apparatus in connection therewith.	W. H. Brothers ..	1890	55

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Maidstone Water Service Mains, Disinfection of the	G. S. Woodhead and W. J. Ware	1900	49
Main Drainage and Sewage Disposal Works, Wimbledon.	W. S. Crimp	1888	73
Main Drainage of Ilford	R. G. Hetherington	1901	173
Main Drainage, The Leicester	E. G. Mawbey	1893	25
Main Drainage Works, Acton	C. N. Lailey	1888	125
Maintenance, Economics of Railway	E. S. Crompton	1870	101
Malting, The Engineering of	H. Stopes	1884	65
Mandalay Railway, The Shan Hill Country and the	E. W. Wagstaff	1899	21
Manufacture, Modern Coal Gas	C. C. Carpenter	1891	61
Manufacture of Coal Gas	A. F. Wilson	1864	35
Manufacture of Iron	E. Riley	1861	59
Marine Boilers, Incrustation in	P. Jensen	1866	117
Marine Boilers, Induced *v.* Forced Draught for	W. A. Martin	1886	111
Marine Course Signalling, International System of	Capt. W. B. Barker	1884	47
Marine Governors	L. Olrick	1862	104
Marine Insurance	G. W. Allan	1858	14
Marine Worms, Action of and Remedies for, at San Francisco.	J. Blackbourn	1874	111
Marshlands, The Inundations of	B. Latham	1862	173
Mechanical Firing of Steam Boilers	J. W. Pearse	1877	31
Mechanical Flight	H. Chatley	1908	241
Mechanical Puddling	P. F. Nursey	1874	77
Mechanical Saws	S. W. Worssam	1867	196
Mechanical Stokers for Electricity Generating Stations	A. Gay	1903	209
Mechanical Traction on Tramways and Roads.	H. Conradi	1908	164
Mechanics of Horse Haulage	T. H. Brigg	1896	21
Mechanics of Dust	C. H. W. Biggs	1909	225
Metallic Bars and Tubes, The Production of, under Pressure.	P. F. Nursey	1901	45
Metallic Preservation and Ornamentation of Iron and Steel Surfaces.	S. O. Cowper-Coles	1905	183
Methods employed in the Determination of the Commercial Value and Purity of Coal Gas.	F. W. Hartley	1869	100
Metric System, The Engineering Pros and Cons of	A. H. Allen	1908	125
Milford Haven and its New Pier Works.	H. Davey	1872	89
Milling Machinery, Roller	J. H. Carter	1883	125
Mineralogy of the Island of Sardinia	C. J. Alford	1879	93
Mining Machinery	E. Edwards	1859	35
Mining Operations in the old kingdom of Sardinia, Laws, &c., relating to	,, ,,	1879	106
Modern Bronze Alloys for Engineering Purposes.	P. F. Nursey	1884	127

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Modern Coal Gas Manufacture	C. C. Carpenter	1891	61
Modern Gas-Engine Practice	S. Griffin	1889	169
Modern Gasworks at Home and Abroad	H. Gore	1868	233
Modern Improvements in the Manufacture of Coal Gas.	R. P. Spice	1886	131
Modern Roadway Construction	H. S. Copland	1878	61
Modern Steel as a Structural Material.	W. W. Beaumont	1880	109
Modern Systems of Generating Steam.	N. J. Suckling	1874	39
Modern Tramway Construction	A. W. Jones	1879	179
Mortars and Cements	G. Robertson	1857	11
Motor Transport for Goods	D. Mackenzie	1903	155
Motor Vehicles, Petroleum	J. D. Roots	1899	95
National Value of Cheap Patents	F. W. Grierson	1880	145
Navigation on the Indus, Steam	A. Warren	1863	139
Need of further Experiments on the Strength of Materials.	C. J. Light	1869	194
New Formula for the Flow of Water in Pipes and Open Channels.	E. C. Thrupp	1887	224
Notes on Cyprus, Engineering	C. J. Alford	1880	131
Notes on Electric Light Engineering	C.H.W. Biggs and W. W. Beaumont	1882	23
Notes on some Twentieth Century Locomotives.	C. Rous-Marten	1902	125
Notes on the Proposed By-laws of the London County Council with respect to House Drainage.	J. P. Barber	1897	17
Nunhead, Shortlands and, Railway	A. G. Drury	1892	219
Nursey, The late Perry F., remarks on, by the President.		1907	155
Obituary		1887	265
,,		1888	253
,,		1889	219
,,		1890	211
,,		1891	215
,,		1892	243
,,		1893	237
,,		1894	253
,,		1895	269
,,		1896	241
,,		1897	201
,,		1898	233
,,		1899	259
,,		1900	267

Subject of Paper.	Author.	Transactions. Year.	Transactions. Page.
Obituary		1901	231
,,		1902	301
,,		1903	231
,,		1904	229
,,		1905	229
,,		1906	273
,,		1907	243
,,		1908	281
,,		1909	244
Obscure Influences of Reciprocation in High-speed Engines.	A. Rigg	1886	83
Opening Bridges on the Furness Railway.	C. J. Light	1885	119
Ores, The Electrolytic Treatment of Complex Sulphide	S. O. Cowper-Coles	1899	203
Paints, The Use of, as an Engineering Material.	E. Spon	1875	69
Panama Railroad, The	Dr. E. Cullen	1868	39
Paper-Making Machinery	R. Henderson	1900	139
Parade Extension Works at Bridlington.	E. R. Matthews	1905	81
Paris Exhibition, Visit to the		1867	151
Parliamentary Procedure as affecting Light Railways and Tramways, Notes on	W. W. Beaumont and S. Sellon	1895	33
Patent Law Practice, British *v.* American	B. H. Thwaite	1902	23
Patent Laws, The	C. D. Abel	1865	25
,, ,, ,,	W. L. Wise	1870	45
Patents, The National Value of Cheap	F. W. Grierson	1880	145
Peat, The Conversion of, into Fuel and Charcoal.	C. E. Hall	1876	151
Peaty Water, The Action of, on a Boiler.	E. Riley	1862	45
Percolation Gauges, Relative Value of	R. E. Middleton	1895	153
Permanent Way of Railways, The	C. J. Light	1859	21
Permanent Way of Railways, The	G. Bowers	1857	11
Perspective	W. Parsey	1859	26
Petroleum Motor Vehicles	J. D. Roots	1899	95
Photographic Surveying	J. B. Lee	1899	171
Photography	F. R. Moultrie	1857	12
Pick's System of Manufacturing Salt in Vacuo.	P. F. Nursey	1890	115
Piers, The Construction of Modern	J. W. Wilson, Jun.	1875	29
Pier Works, Milford Haven and its New	H. Davey	1872	89
Pile-Driving	H. O'Connor	1894	71

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Piles, Screw	H. P. Stephenson ..	1857	12
Piling and Coffer Dams	F. W. Bryant ..	1859	38
Pin-connected *v.* Riveted Bridges..	J. H. Cunningham..	1889	131
Pioneer and Portable Railways ..	J. Kerr	1891	89
Pipes Sewers of Croydon and the Causes of their Failure, The	J. T. Kershaw ..	1860	52
Pits and Hauling Machinery for the San Domingos Mines in Portugal.	J. Bernays	1879	29
Pollution of Water, and its Correction.	R. E. Middleton ..	1897	173
Portable and Pioneer Railways ..	J. Kerr	1891	89
Portland Cement	H. Faija	1885	95
Portland Cement, Effect of Sea Water on	,, ,, ...	1888	39
Portland Cement, some Points in its Testing, Uses and Abuses.	D. B. Butler	1895	61
Portland Cement, The Effect of Admixtures of Kentish Ragstone, &c., upon	,, ,, ...	1896	179
Potable Waters, The Chemistry and Bacteriology of	D. Sommerville ..	1906	67
Power Distribution by Electricity, Water and Gas.	E. C. de Segundo ..	1894	143
Practical Construction in the Colonies.	W. G. Ferrar	1875	53
Practical Examples of Blasting, Some	P. F. Nursey	1893	201
Practice of Foundry Work	H. R. Hooper ..	1888	191
Preparation of Rhea Fibre for Textile Purposes, The	P. F. Nursey	1898	177
Preservation and Ornamentation of Iron and Steel Surfaces.	G. Bower	1883	59
Pressure Gauges, Gas Meters and ..	J. Willcock	1860	37
Prevention of the Bacterial Contamination of Streams and Oyster Beds.	W. P. Digby and H. C. H. Shenton	1906	229
Prevention of Smoke	A. C. Engert	1881	101
Prevention of Leakage in Gas and Water Mains.	C. M. Barker	1869	79
Primary Batteries for Illuminating Purposes.	P. F. Nursey ..	1887	185
Priming of Steam Boilers	W. Major	1877	59
Principles and Practice of Hydro-extraction, The	H. B. Ransom ..	1894	227
Propeller, The Screw	A. Rigg	1868	202
Propellers, Screw ; their Shafts and Fittings.	H. W. Pendred ..	1875	151
Propulsion, The Theory of Screw ..	M. Sefi	1870	82
Protection of Underground Water Supplies, The	J. C. Thresh	1898	47
Protective Metallic Coatings for Iron and Steel.	S. O. Cowper-Coles	1898	139

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Puddling Furnace, The Dephosphorisation of Iron in	P. S. Justice	1885	169
Puddling, Mechanical	P. F. Nursey	1874	77
Pumping Engine, The Use of the Cornish	A. Fraser	1864	78
Pumping Engines	W. T. Carrington ..	1859	19
Pumping Engines, Direct-acting ..	P. B. Björling ..	1877	79
Pumping Engines for Mines, Recent Improvements in	H. Davey	1873	182
Pumping Engines for Town Water Supply.	,, ,, ...	1867	88
Pumping Machinery, The Underground, at the Erin Colliery, Westphalia.	,, ,, ...	1876	119
Pump Valves	J. Hendry	1859	25
Quality of Iron, as now used	E. Matheson	1867	168
Quartz Crushing Machinery	P. F. Nursey	1860	17
Railway Amalgamation, State Railways and	G. Spencer	1872	43
Railway Axles, The Strength of Wrought-iron	T. Andrews	1879	143
Railway Axles, The Effect of Strain on, and the Minimum Flexion-Resistance Point in Axles.	,, ,, ...	1895	181
Railway Brakes, Continuous ..	W. H. Fox	1872	112
,, ,, ,, ..	,, ,, ...	1873	33
Railway Bridge at the Place de l'Europe	T. Cargill	1866	191
Railway Bridge over the Thames, The Charing Cross	M. Parkes	1864	166
Railway Bridges for Branch Lines, Examples of	M. A. Pollard-Urquhart	1896	117
Railway Maintenance, The Economics of	E. S. Crompton ..	1870	101
Railway Surveys and Design in New Countries, Notes on	P. G. Scott	1904	103
Railway Switches and Crossings ..	C. J. Light	1857	13
Railway, The Shortlands and Nunhead	A. G. Drury	1892	219
Railway, The Channel	P. F. Nursey	1876	17
Railway Train Intercommunication	S. A. Varley	1873	162
Railway Tunnelling in Japan ..	T. M. Rymer-Jones	1882	101
Railway Turntables	,, ,, ..	1858	11
Railway Wheels, Elastic	V. Pendred	1864	119
Railways, Horse, and Street Tramways.	H. Gore	1873	113
Railways, Light	W. Lawford	1888	161
Railways, Portable and Pioneer ..	J. Kerr	1891	89

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Railways, Street	C. J. Light	1860	56
Railways, The Permanent Way of	G. Bowers	1857	11
,, ,, ,,	C. J. Light	1859	21
Rainfall, Influence of, on Design of Sewers.	C. A. Battiscombe	1909	93
Rating of Engineering Undertakings.	P. M. Faraday	1897	43
Recent Blast Furnace Practice	B. D. Healey	1902	97
Recent Developments in High Explosives.	P. F. Nursey	1889	71
Recent Practice in Sewage Disposal	H. C. H. Shenton	1900	217
Recent Storage Battery Improvements.	S. O. Cowper-Coles	1906	201
Reciprocation, Obscure Influences of, in High-speed Engines.	A. Rigg	1886	83
Redhill Sewage Works, The	S. A. Reade	1868	168
Refrigerating Machine on the Linde System, Trial of	T. B. Lightfoot	1891	39
Refrigerating Machinery on Board Ship	,, ,,	1887	105
Relation between the Safe Load and ultimate Strength of Iron.	Z. Colburn	1863	35
Relative Value of Percolation Gauges	R. E. Middleton	1895	153
Renewal of Roof over Departure Platform at King's Cross Terminus, G.N.R.	R. M. Bancroft	1887	125
Repair of the River Bank, The Explosion at Erith and the	L. G. Moore	1864	183
Reservoir Embankments	W. Fox	1898	23
Reservoirs, Storage, The Designing and Construction of	A. Jacob	1866	225
Rhea Fibre for Textile Purposes, The Preparation of	P. F. Nursey	1898	177
Rigidity, Strength and	W. E. Kochs	1865	69
River Pollution caused by Sewage Disposal.	G. B. Jerram	1886	217
River Thames, Wooden Jetties on the	J. G. Davenport	1860	24
Riveted, Pin-connected Bridges *v.*	J. H. Cunningham	1889	135
Roads, Bridle-, in the West Indies	H. C. Huggins	1907	193
Road Bridges of Charing Cross Railway	M. Parkes	1864	143
Road Maintenance and Administration.	R. J. Thomas	1903	49
Road Surfaces, Treatment and Formation of	A. J. Metcalfe	1908	25
Road Traffic in and near Large Cities (Topical discussion) opened by	W. W. Beaumont	1903	23
Road-Train System, Renard and Sourcouf	B. H. Thwaite and R. F. Thorpe	1907	43
Roads, The Construction and Repair of	G. R. Strachan	1889	17

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Roadway Construction, Modern ..	H. S. Copland ..	1878	61
Roller-milling Machinery	J. H. Carter	1883	125
Rolling of Ships	W. McNaught ..	1876	187
Rolling Stock, Statistics of British and American	W. P. Digby	1905	49
Roof, Renewal of, over Departure Platform at King's Cross Terminus, G.N.R.	R. M. Bancroft ..	1887	125
Roofs, Arched	C. R. von Wessely	1866	36
Roofs, Iron	A. T. Walmisley ..	1881	123
Roorkee Hydraulic Experiments ..	E. S. Bellasis	1886	41
Rural Sanitation	G. W. Usill	1877	113
Safe Load and Ultimate Strength of Iron, Relation between	Z. Colburn	1863	35
Safety Appliances for Elevators ..	H. W. Umney ..	1895	113
Safety Valves for Steam Boilers, &c.	T. Baldwin	1867	23
Salt, Pick's System of Manufacturing, in Vacuo.	P. F. Nursey	1890	115
Sanitary and Industrial, Water Purification	J. W. Pearse	1878	29
Sardinia, The Mineralogy of the Island of	C. J. Alford	1879	93
Saws, Mechanical	S. W. Worssam ..	1867	196
Screw Piles	H. P. Stephenson ..	1857	12
Screw Piles in the Construction of a Wrought-iron Bridge at Verona.	J. G. Horner	1867	52
Screw Propeller, The	A. Rigg	1868	202
Screw Propellers, their Shafts and Fittings.	H. W. Pendred ..	1875	151
Screw Propulsion, The Theory of ..	M. Sefi	1870	82
Sea and other Banks, Construction of	E. Olander	1862	25
Sea Defences	R. F. Grantham ..	1897	143
Sea Water, Effect on Portland Cement.	H. Faija	1888	39
Secondary Generators, Distribution of Electrical Energy by	J. D. Gibbs	1885	49
Segregation, Effect of, on the Strength of Steel Rails.	T. Andrews	1902	209
Sensitiveness and Isochronism in Governors.	A. Rigg	1880	73
Sewage, Bacterial Treatment of ..	G. Thudichum ..	1898	207
Sewage, The Bacterial Treatment of	,, ,, ..	1903	185
Sewage Disposal	H. Robinson	1879	197
Sewage Disposal, Recent Practice in	H. C. H. Shenton ..	1900	217
Sewage Disposal, The Latest Practice in	,, ,, ..	1904	41
Sewage Disposal, River Pollution caused by	G. B. Jerram	1886	217

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Sewage Disposal Works, and Main Drainage, Wimbledon	W. S. Crimp	1888	73
Sewage, Irrigation with Town ..	G. King	1865	84
Sewage Matter, A new System of treating	H. Olrick	1883	23
Sewage Precipitation Works, Foreign	A. Wollheim	1892	123
Sewage Purification, The Chemistry and Bacteriology of	D. Sommerville ..	1909	175
Sewage Question during the last Century, The	H. A. Roechling ..	1901	193
Sewage Sludge, Filter Presses for ..	J. Croll	1897	121
Sewage, The Forms and Construction of Channels for the Conveyance of	J. Phillips	1874	145
Sewage, Ultimate Purification of ..	G. Thudichum ..	1896	199
Sewage, Utilisation of	B. Latham	1866	68
Sewage Works, Redhill	S. A. Reade	1868	168
Sewerage System, The Shone Hydro-Pneumatic	E. Ault	1887	68
Sewer Ventilation	W. S. Crimp	1890	139
Sewers, Influence of Rainfall on the Design of	C. A. Battiscombe	1909	93
Sewers, Pipe, The Cleansing and Ventilation of	B. A. Miller	1892	167
Sewers, Ventilation of	B. Latham	1871	39
Shan Hill Country and the Mandalay Railway, The	E. W. Wagstaff ..	1899	21
Ship Caissons for Dock Basins and Dry Docks.	J. J. F. Andrews ..	1890	189
Ship Canal between the Atlantic and Pacific Oceans, The Surveys for	Dr. E. Cullen	1868	15
Ship Canal, The Isthmus of Darien and the	,, ,, ...	1868	52
Ships, Apparatus for Measuring the Velocity of	V. Pendred	1869	215
Ships, The Rolling of	W. McNaught ..	1876	187
Shone Hydro-Pneumatic Sewerage System	E. Ault	1887	68
Shortlands and Nunhead Railway	A. G. Drury	1892	219
Signalling for Land and Naval purposes	F. Wise	1863	117
Single and Double-riveted Joints ..	T. Baldwin	1866	150
Sinlumkaba Bridge, The	W. E. Haldwell ..	1909	121
Slag, Economic Use of Blast-furnace	P. F. Nursey	1873	196
Slide-valve, The Friction of, and its appendages.	T. Adams	1866	6
Slopes of Earthwork, A new Method of Setting-out	C. J. Light	1873	216
Small Towns and Rural Districts, Water Supply of	P. Griffith	1896	55
Smoke, Prevention of	A. C. Engert	1881	101

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Society's History, The: a Jubilee Retrospect.	P. F. Nursey	1904	65
Soft *v.* Hard Water for Manufacturing Purposes.	J. C. Fell	1884	103
Soil, Application of Steam to the Cultivation of the	B. Latham	1868	274
Stability of Chimney Shafts	R. J. Hutton	1887	150
State Railways and Railway Amalgamation.	G. Spencer	1872	43
Statistics of British and American Rolling Stock.	W. P. Digby	1905	49
Status Prize Essay	G. A. Thomas	1909	147
Steam, Apparatus for Utilising the Waste Heat of Exhaust	J. Atkinson	1878	167
Steam Boilers, Corrosion in	J. H. Paul	1891	147
Steam Boilers, The Defects of, and their Remedy.	A. C. Engert	1884	25
Steam Boiler Explosions	P. F. Nursey	1863	1
Steam Boilers, Experimental Researches into the Nature and Action of	T. Baldwin	1867	23
Steam Boilers, The Priming of	W. Major	1877	59
Steam Boilers, Mechanical Firing of	J. W. Pearse	1877	31
Steam Boilers, Water and its effect on	H. K. Bamber	1867	65
Steam Carriages	A. F. Yarrow	1862	128
Steam Cylinders, Equalising the Wear in Horizontal	W. Schönheyder	1878	45
Steam Cylinders, Friction in	P. Jensen	1870	17
Steam Fire Engines, and the late trial at the Crystal Palace.	W. Roberts	1863	163
Steam, High Pressure, and Steam Engine Efficiency.	W. W. Beaumont	1888	221
Steam, Modern Systems of Generating	N. J. Suckling	1874	39
Steam Navigation on the Indus	A. Warren	1863	139
Steam, Generation and Expansion of	W. T. Carrington	1858	15
Steam, The Utilisation of Town Refuse for generating	T. W. Baker	1894	183
Steam Wagons	J. C. Cornock	1909	207
Steel, Modern, as a structural Material.	W. W. Beaumont	1880	109
Steel Needles, The Use of, in driving a Tunnel at King's Cross.	W. H. Holttum	1892	199
Steel Rails, Effect of Segregation on the Strength of	T. Andrews	1902	209
Steel Reinforcement, Corrosion of, in Concrete.	E. R. Matthews	1909	61
Steel Wagon and Carriage Frames, Fox's System of Solid-pressed	P. F. Nursey	1889	197
Stokers, Machine, for Gas Retorts	H. O'Connor	1891	117
Stone-sawing Machinery	H. Conradi	1876	135

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Stone Quarries and their Working, The Grindleford	B. L. Bradley	1905	201
Storage Battery Improvements, Recent	S. O. Cowper-Coles	1906	201
Storage Reservoirs, Designing and Construction of	A. Jacob	1866	225
Street Railways	C. J. Light	1860	56
Street Subways for Large Towns	C. Mason	1895	91
Street Tramways, Horse Railways and	H. Gore	1873	113
Strength and Rigidity	W. E. Kochs	1865	69
Strength of Flues in Lancashire and similar Boilers.	W. Martin	1882	157
Strength of Materials, Need of further Experiments on the	C. J. Light	1869	194
Strength of Suspension Bridges, The	C. E. Browning	1858	11
Strength of Wrought-Iron Railway Axles.	T. Andrews	1879	143
Subaqueous Operations	H. B. Thomas	1907	213
Submarine Groyning	G. O. Case	1906	107
Submerged Chain Cable Groynes	R. G. Allanson-Winn	1906	13
Substitutes, Gas	V. B. Lewes	1893	141
Subways, Concrete, for Underground Pipes.	A. T. Allen	1901	99
Subways for Large Towns, Street	C. Mason	1895	91
Sugar-making Machinery	P. F. Nursey	1865	155
Sugar Machinery, Recent Practice in Cane-	,, ,,	1906	149
Super-heating of Steam, and the various Appliances employed therein.	,, ,,	1861	36
Supply of Water to Towns	B. Latham	1864	199
Surface Condensers	J. Louch	1861	96
Suspension Bridges	R. M. Ordish	1857	13
Switches and Crossings, Railway	C. J. Light	1857	13
Tables, Circular	H. Hakewill	1865	147
Telegraph Instruments, Electric	E. G. Bartholomew	1872	53
Telegraph, The Electric	W. Ansell	1857	11
Telegraphy, Electric, irrespective of Telegraphic apparatus.	,, ,,	1869	55
Testimonial to Mr. Alfred Williams	.. ..	1868	161
Thames Graving Dock, The New Hydraulic Machinery for lifting Vessels in the	J. Amos	1859	17
Theory of Screw Propulsion	M. Sefi	1870	82
Tidal Approaches and Deep-water Entrances.	J. B. Redman	1885	143
Tidal Energy, Utilisation of	A. Oates	1882	81
Timber Bridges, Australian	H. E. Bellamy	1902	63

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Timbering of Trenches and Tunnels	C. Turner	1871	90
Tin-dressing Machinery, Recent Improvements in	S. H. Cox	1874	11
Tools, Machine	E. C. Amos	1899	51
Town Houses, Drainage of	G. M. Lawford	1891	187
Town Refuse, The Economical Disposal of	B. D. Healey	1900	65
Town Sewage, Irrigation with	G. King	1865	84
Towns, Supply of Water to	B. Latham	1864	199
Town Water Supply, Pumping Engines for	H. Davey	1867	88
Traction, Electrical, and its Financial Aspect.	S. Sellon	1892	37
Traction, Mechanical, on Tramways and Roads.	H. Conradi	1908	164
Tramway Construction, Modern	A. W. Jones	1879	179
Tramway Rolling Stock, and Steam in connection therewith.	C. C. Cramp	1874	119
Tramway and other Rails, The Cleaning of	H. Conradi	1893	47
Tramways, Cable	W. N. Colam	1885	69
Transport Possibilities of our Inland Waterways.	B. H. Thwaite	1905	19
Treating Sewage Matter, A new system of	H. Olrick	1883	23
Treatment and Formation of Road Surfaces.	A. J. Metcalfe	1908	25
Treatment and Utilisation of Exhaust Steam.	P. Griffith	1890	163
Trial of a Refrigerating Machine on the Linde System.	T. B. Lightfoot	1891	39
Trussed Beams	W. Parsey	1862	52
Tube Wells	A. Le Grand	1877	133
Tube Wells for large Water Supply	R. Sutcliff	1877	149
Tunnelling, Railway, in Japan	T. M. Rymer-Jones	1882	101
Tunnels, Timbering of Trenches and	C. Turner	1871	90
Tunnel, The Use of Steel Needles in driving, at King's Cross.	W. H. Holttum	1892	199
Turntables, Railway	C. J. Light	1858	11
Ultimate Purification of Sewage	G. Thudichum	1896	199
Underground Pumping Machinery at the Erin Colliery, Westphalia.	H. Davey	1876	119
Use of Coal in Furnaces without Smoke	C. F. T. Young	1862	66
Use of Steel Needles in driving a Tunnel at King's Cross.	W. H. Holttum	1892	199
Utensils of a Brewery, Machinery and	T. Wilkins	1871	10
Utilisation of Coal Slack in the Manufacture of Coke for Smelting	G. M. Ward	1880	33

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Utilisation of Sewage	B. Latham	1866	68
Utilisation of Tidal Energy	A. Oates	1882	81
Utilisation of Town Refuse for generating Steam	T. W. Baker	1894	183
Utilisation of Waste Mineral Substances	E. Edwards	1861	82
Utilisation of Water Power, The	G. L. Molesworth	1858	16
Vacation Visits		1878	119
,, ,,		1879	141
,, ,,		1880	89
,, ,,		1881	121
,, ,,		1882	119
,, ,,		1883	85
,, ,,		1884	119
,, ,,		1885	113
,, ,,		1886	153
,, ,,		1887	145
,, ,,		1888	148
,, ,,		1889	131
,, ,,		1890	133
,, ,,		1891	111
,, ,,		1892	157
,, ,,		1893	133
.. ,,		1894	177
,, ,,		1895	145
,, ,,		1896	137
,, ,,		1897	115
,, ,,		1898	127
,, ,,		1899	161
,, ,,		1900	133
,, ,,		1901	137
,, ,,		1902	155
,, ,,		1903	143
,, ,,		1904	129
,, ,,		1905	145
,, ,,		1906	139
,, ,,		1907	151
,, ,,		1908	157
,, ,,		1909	141
Value of Exhibitions as Aids to Engineering Progress.	S. Barnett	1883	75
Value of Cheap Patents, The National	E. W. Grierson	1880	145
Valves, Pump	J. Hendry	1859	25
Velocity of Ships, Apparatus for Measuring the	V. Pendred	1869	215
Ventilation and Warming	W. T. Sugg	1895	235
Ventilation, Cleansing and, of Pipe Sewers.	B. A. Miller	1892	167
Ventilation, Flues and	A. H. C. Trewman	1876	91

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Ventilation of Buildings	J. W. Pearse	1876	97
Ventilation of Coal Mines	G. G. André	1874	23
Ventilation of Sewers	B. Latham	1871	39
Ventilation, Sewer	W. S. Crimp	1890	139
Verona, Screw Piles in the construction of Wrought-iron Bridge at	J. G. Horner	1867	52
Visit to the Paris Exhibition		1867	151
Visit to Leeds		1909	203
Waggon and Carriage Frames, Fox's Patent System of Solid-pressed Steel	P. F. Nursey	1889	197
Waste Heat of Exhaust Steam, Apparatus for Utilising the	J. Atkinson	1878	167
Waste Mineral Substances, The Utilisation of	E. Edwards	1861	82
Water and its effects on Steam Boilers.	H. K. Bamber	1867	65
Water, The Pollution of, and its Correction.	R. E. Middleton	1897	173
Water Power, The Utilisation of	G. L. Molesworth	1858	16
Water Pressure, Application of, to Machine Tools and Appliances.	R. H. Tweddell	1890	35
Water Purification, Sanitary and Industrial.	J. W. Pearse	1878	29
Water, Soft *v.* Hard, for Manufacturing purposes.	J. C. Fell	1884	103
Water Softening, by Dr. Clarke's Process	J. Glynn, jun.	1859	29
Water Supplies, The Protection of Underground	J. C. Thresh	1898	47
Water, Supply of, to Towns	B. Latham	1864	199
Water Supply, Preliminary Investigations for	S. A. Hollis	1901	147
Water Supply, Pumping-engines for Town	H. Davey	1867	88
Water Supply at Penzance, Some Recent Works of	F. Latham	1904	11
Water Supply to the Town of Fareham, Drainage and	T. Buckham	1869	41
Water Supply of Small Towns and Rural Districts.	P. Griffith	1896	55
Water Supply to Country Mansions and Estates.	G. Harris	1899	231
Water-tube Boilers	V. Pendred	1867	109
Waterways, The Transport Possibilities of our Inland Navigable	B. H. Thwaite	1905	19
Waterworks Construction in America	E. R. Matthews	1907	77
Wear in Horizontal Steam Cylinders, Equalising the	W. Schönheyder	1878	45

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Weighing Machinery and Automamatic Apparatus in connection therewith.	W. H. Brothers ..	1890	55
Wells, Tube	A. Le Grand	1877	133
Wells, Tube, for large Water Supply	R. Sutcliff	1877	149
Wheels, Elastic Railway..	V. Pendred	1864	119
Wheel Teeth, The Design and the Waste.and Wear of	Prof. R. H. Smith ..	1908	81
Wimbledon Main Drainage and Sewage Disposal Works.	W. S. Crimp	1888	73
Wooden Jetties on the River Thames	J. G. Davenport ..	1860	24
Worms, The Action of Marine, and Remedies employed in the Harbour of San Francisco.	J. Blackbourn ..	1874	111
Wrought Iron, The Extension and Permanent Set of	C. E. Browning ..	1858	15

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